

KLOTZ & MILES

**The Effect of Fillets on the
Strength of Cast Iron Machine Parts**

Mechanical Engineering

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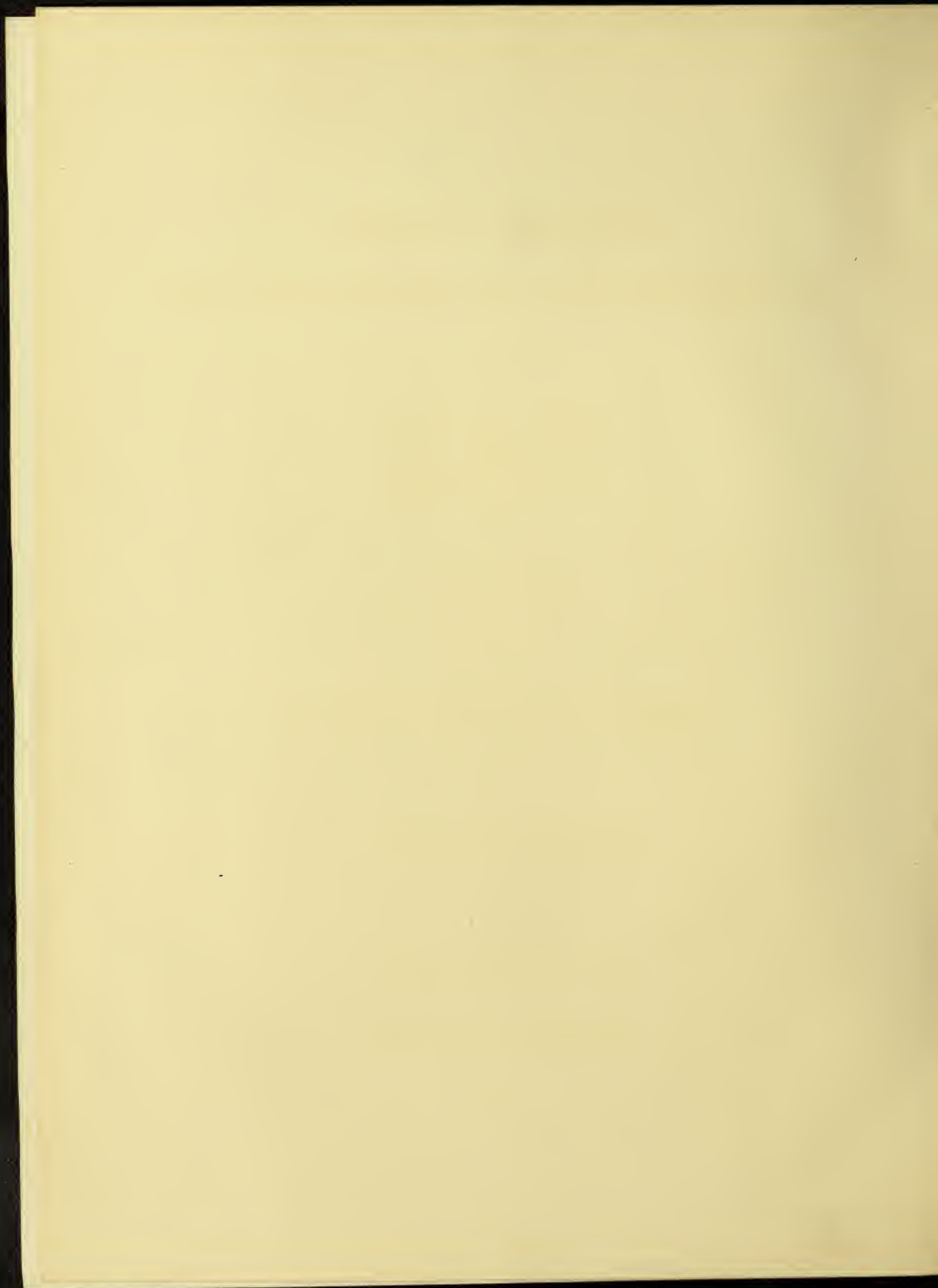
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**THE EFFECT OF FILLETS
ON THE STRENGTH OF CAST IRON MACHINE PARTS**

BY

**HARRY JOHN KLOTZ
AND
PAUL KEITER MILES**

THE S I S

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Harry John Klotz and Paul Keiter Miles

ENTITLED The Effect of Fillets on the Strength of Cast Iron
Machine Parts

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in

Mechanical Engineering.

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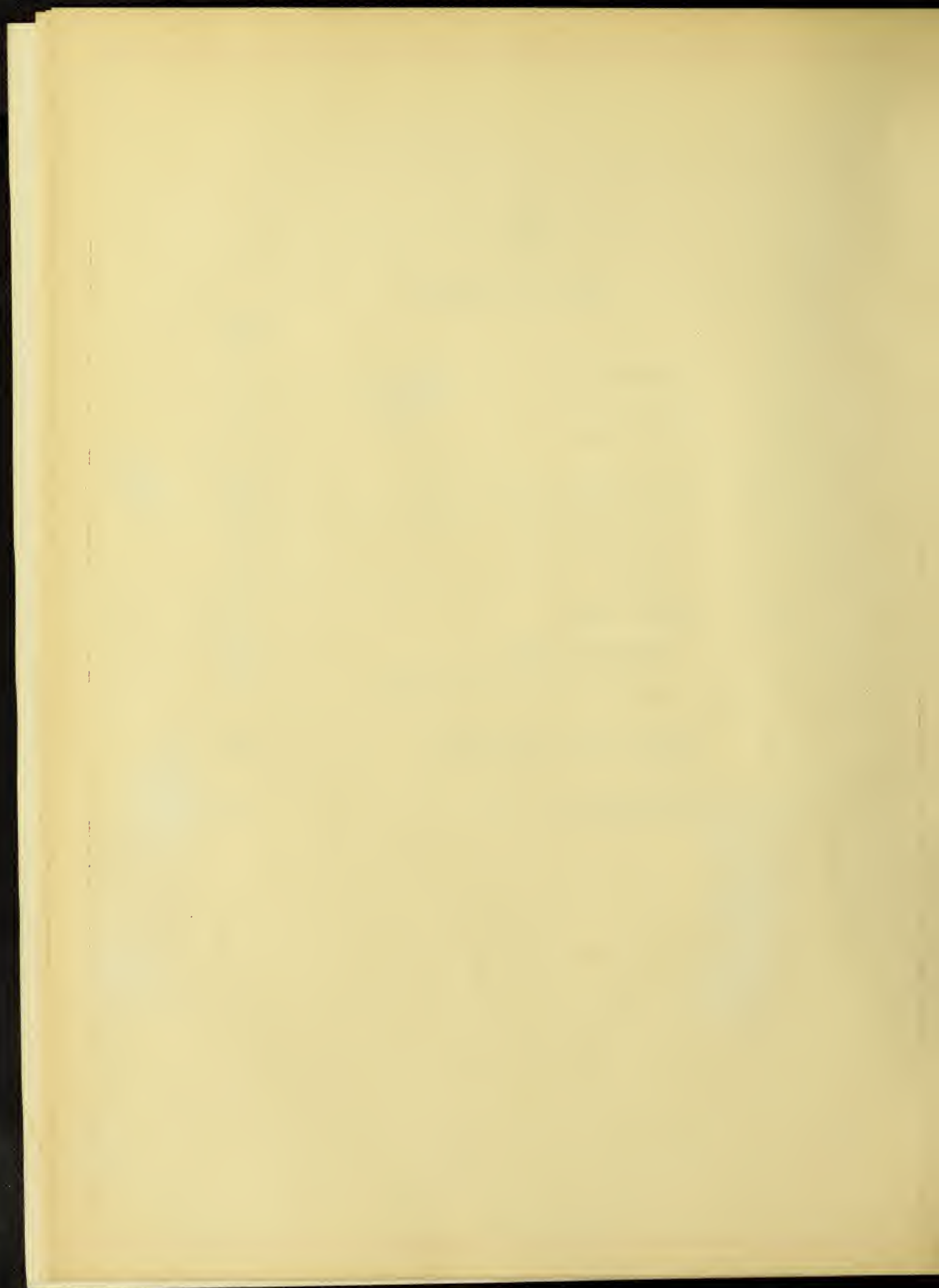
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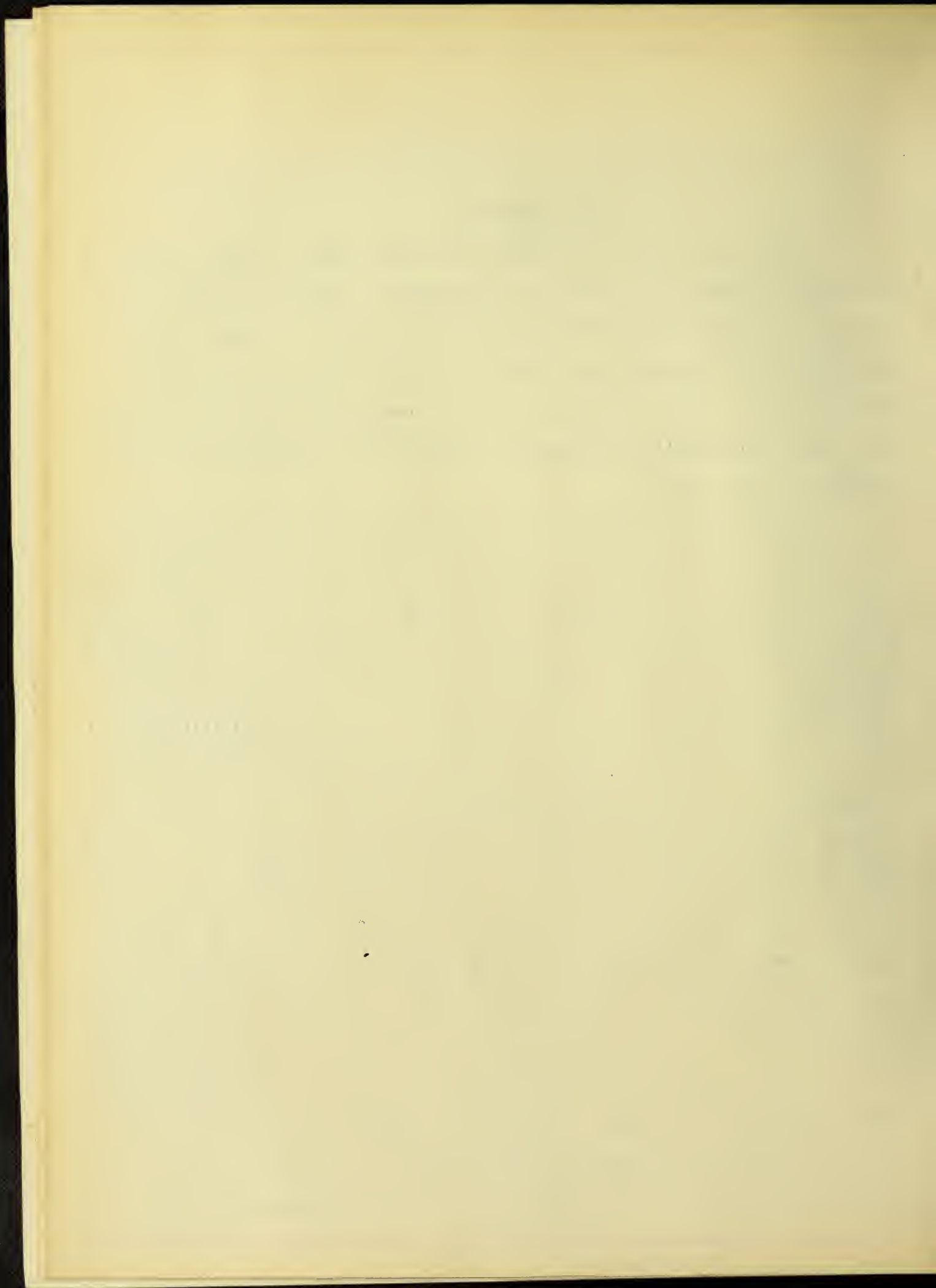


I

INTRODUCTION.

The fact that the strength of pieces made of cast iron is increased by means of filleting the corners is generally known. But as far as a quantitative expression of the relation between the dimensions of the section and the radius of the fillet is concerned, no information has been available to guide designers. As was discovered when this investigation was under contemplation, information on the subject is very meager.

The lack of tests on this subject may be explained by two facts. First, as is generally known, cast iron is at best a very difficult material to investigate on account of its variation in quality. The results that are obtained by experiment and in practice have been found to be so at variance with those predicted by theory that the assumptions on which the theory is based must be seriously in error. This is due, no doubt, to the irregularities in cast iron. No assurance can be had that the quality of iron in any two pieces is near enough the same to permit of an absolute comparison. In fact, experience shows that the quality of metal in different parts of a given specimen may vary considerably. The second reason for the absence of data on this subject is that designers have been content to pass over the problem without giving it due consideration. The usual practice has been to let the radius of the fillet be governed by the general proportions of the piece. Under this mode of procedure, mistakes are bound to be made, and with the extent to which cast iron is used in present day machine construction, it is readily seen that definite knowledge on the subject is really of considerable import-



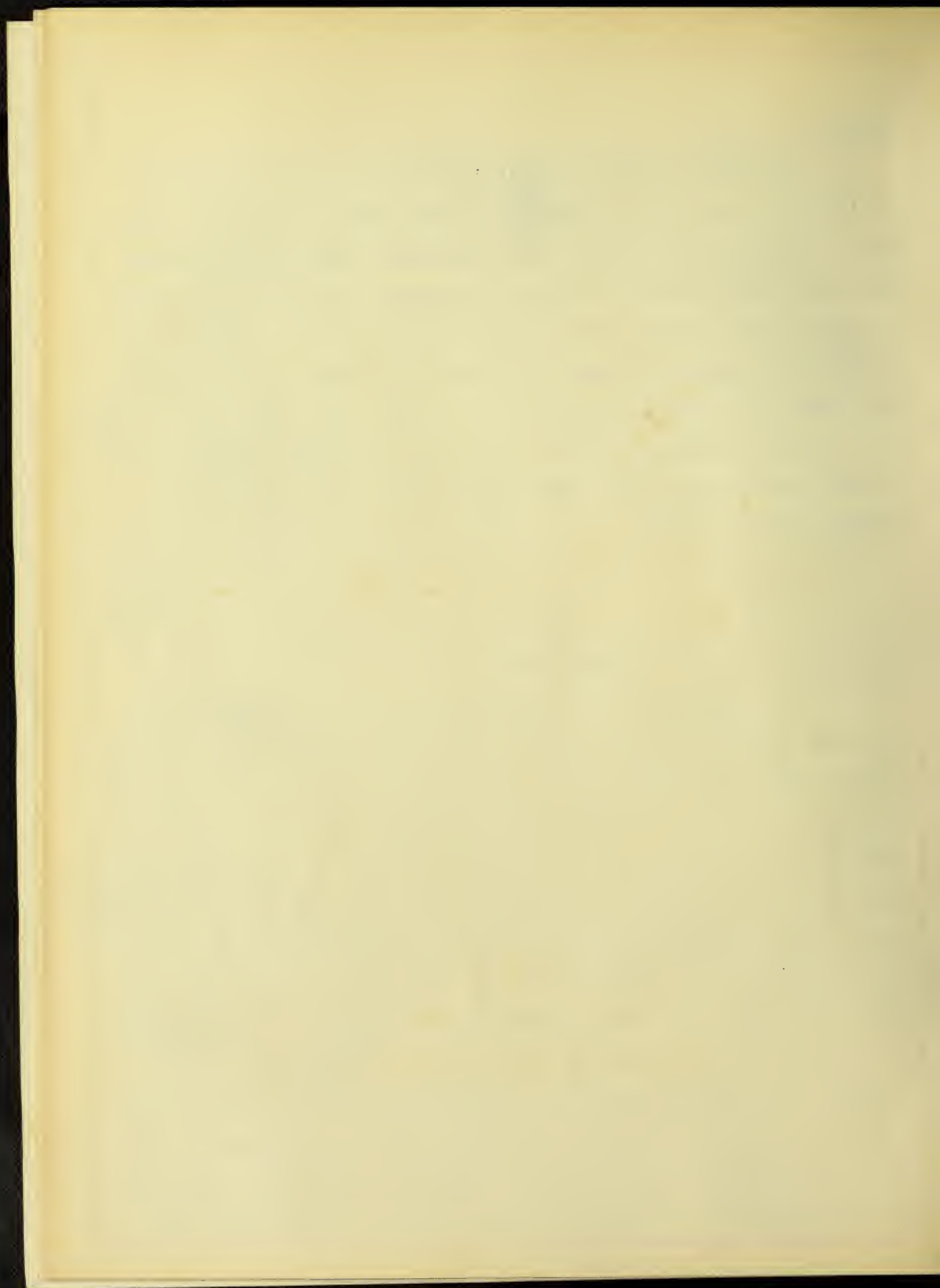
ance.

It was to secure definite information which will help in deciding on the radius of the fillet that should be used in a given case, that this investigation was undertaken. The writers realized that any results obtained would be of greater qualitative than quantitative value, because of the nature of the material under investigation. The attempt was made to attack the problem from as nearly a practical standpoint as possible, as will be shown under the description of test pieces. It was the belief of the writers that the tests planned would lead to some experimental basis for selecting the proper size of fillet.

II

TEST PIECES

The character of the specimen which it was decided to use is shown by Fig. 1 on the following page. The specimen was so designed that while the radius of the fillet might be varied, the depth of the section through the fillet and the moment arm of the applied force about that section would be kept constant. It was imperative that these two factors be maintained constant, in order that the results obtained from specimens with different radii of fillets could be compared and the effect of the fillets shown directly. The piece was designed by the straight beam formula in ordinary use, to break at a load of 10,000 pounds, as this load was a convenient one to handle on the testing machine at the disposal of the writers. It is believed that this test piece is more or less representative of conditions found in actual practice. It was recognized that cast iron is seldom used where subjected to pure tension. However, many cast



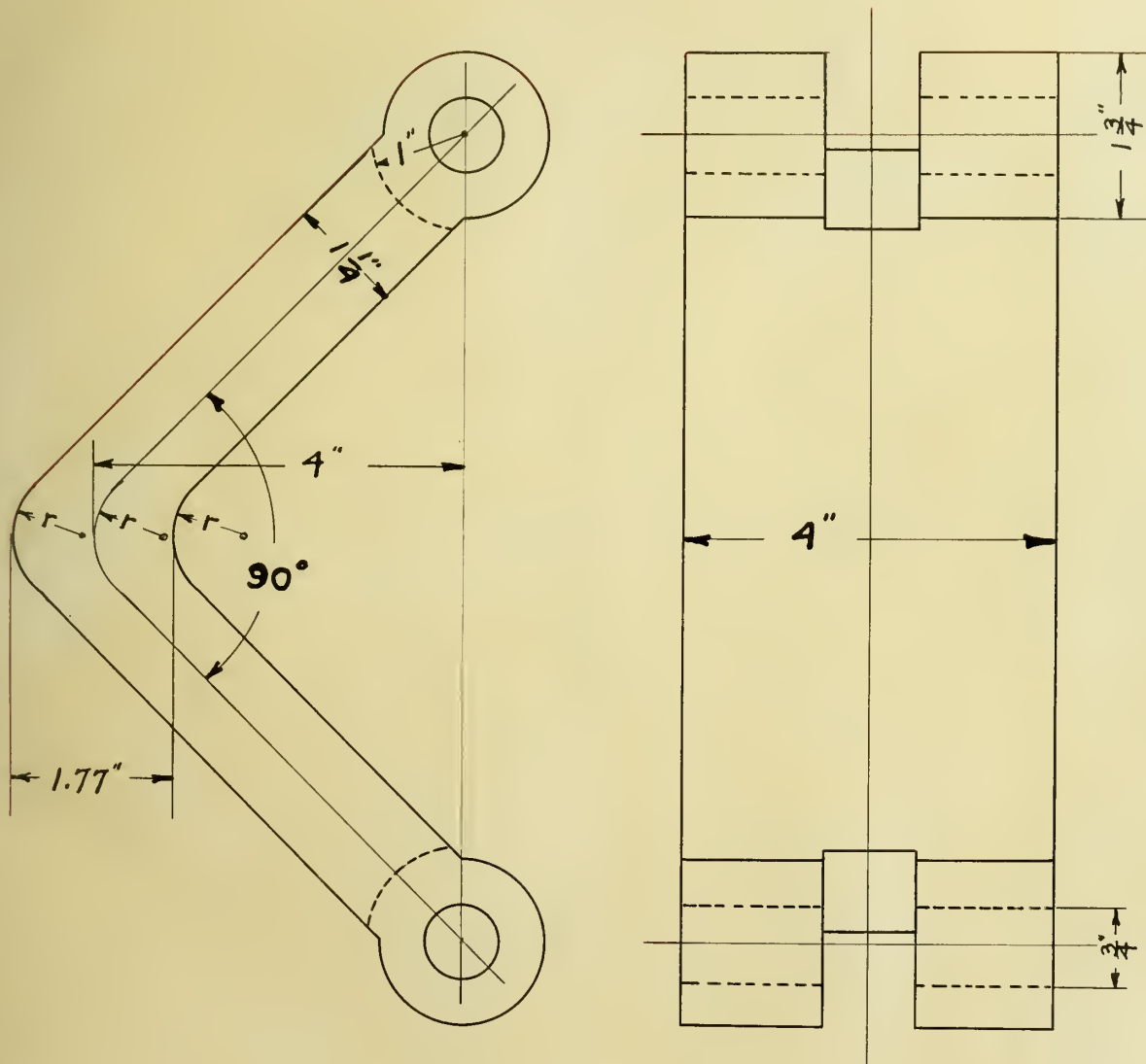
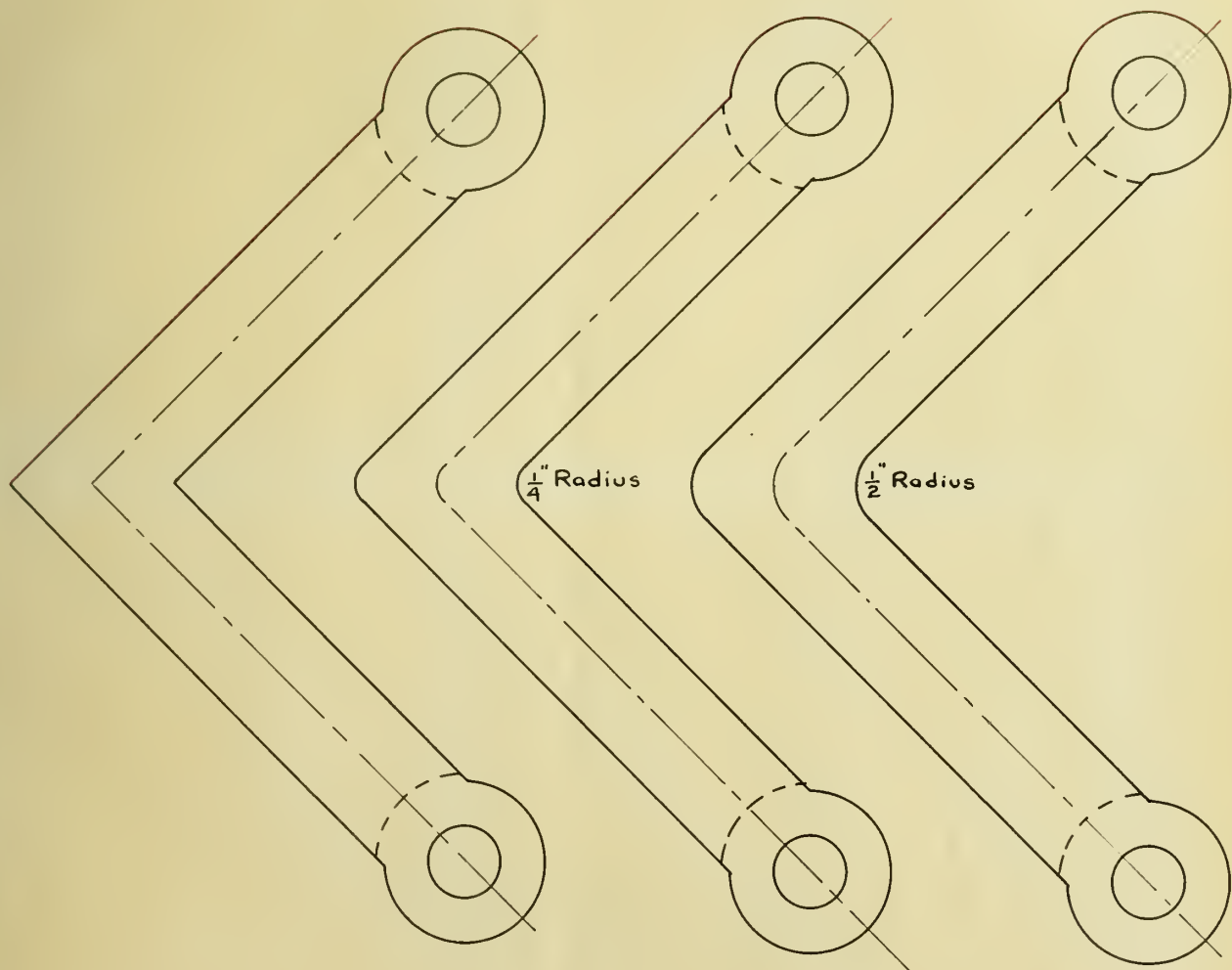


Fig. 1
 Test Piece for
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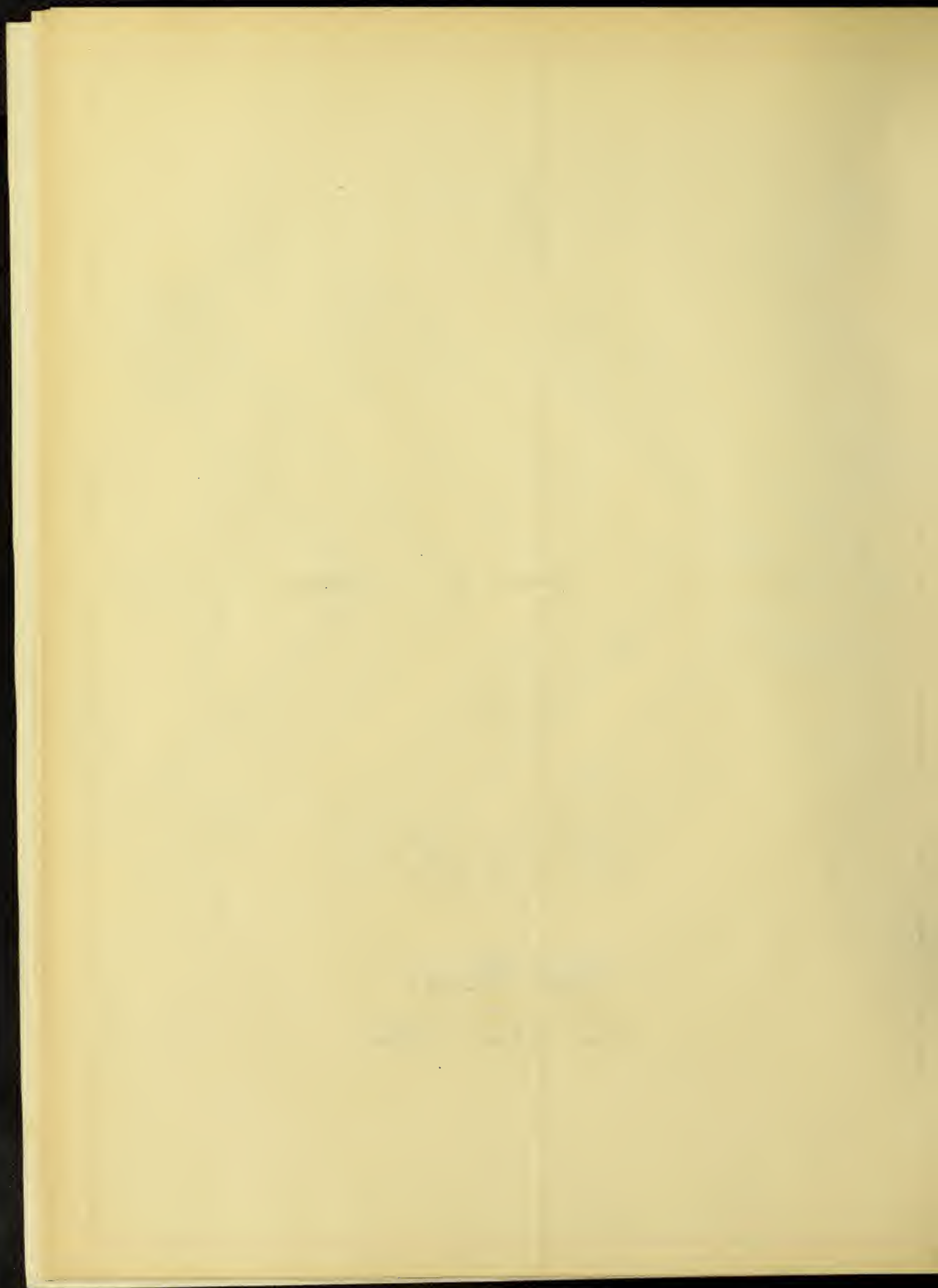


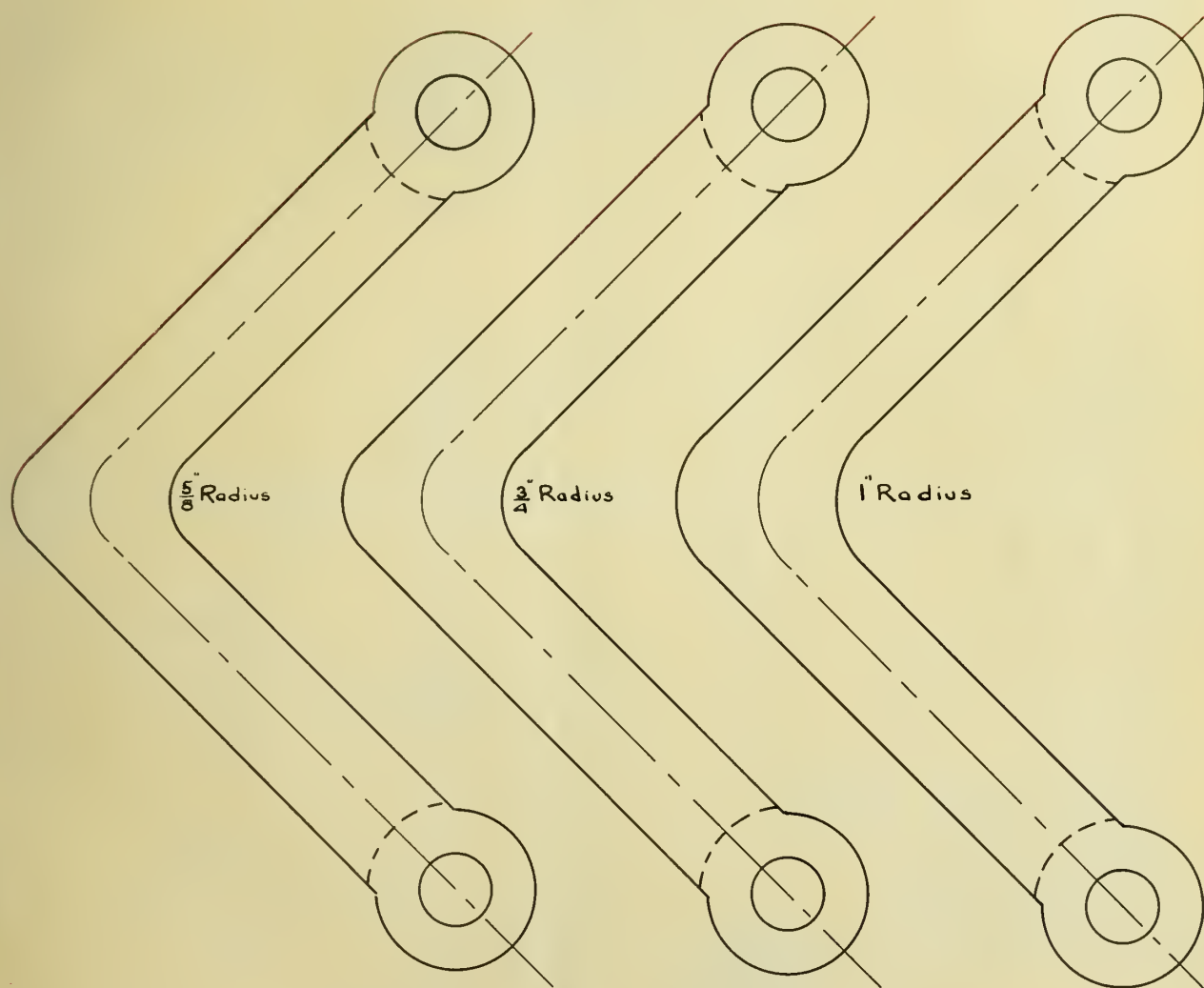


TEST PIECES

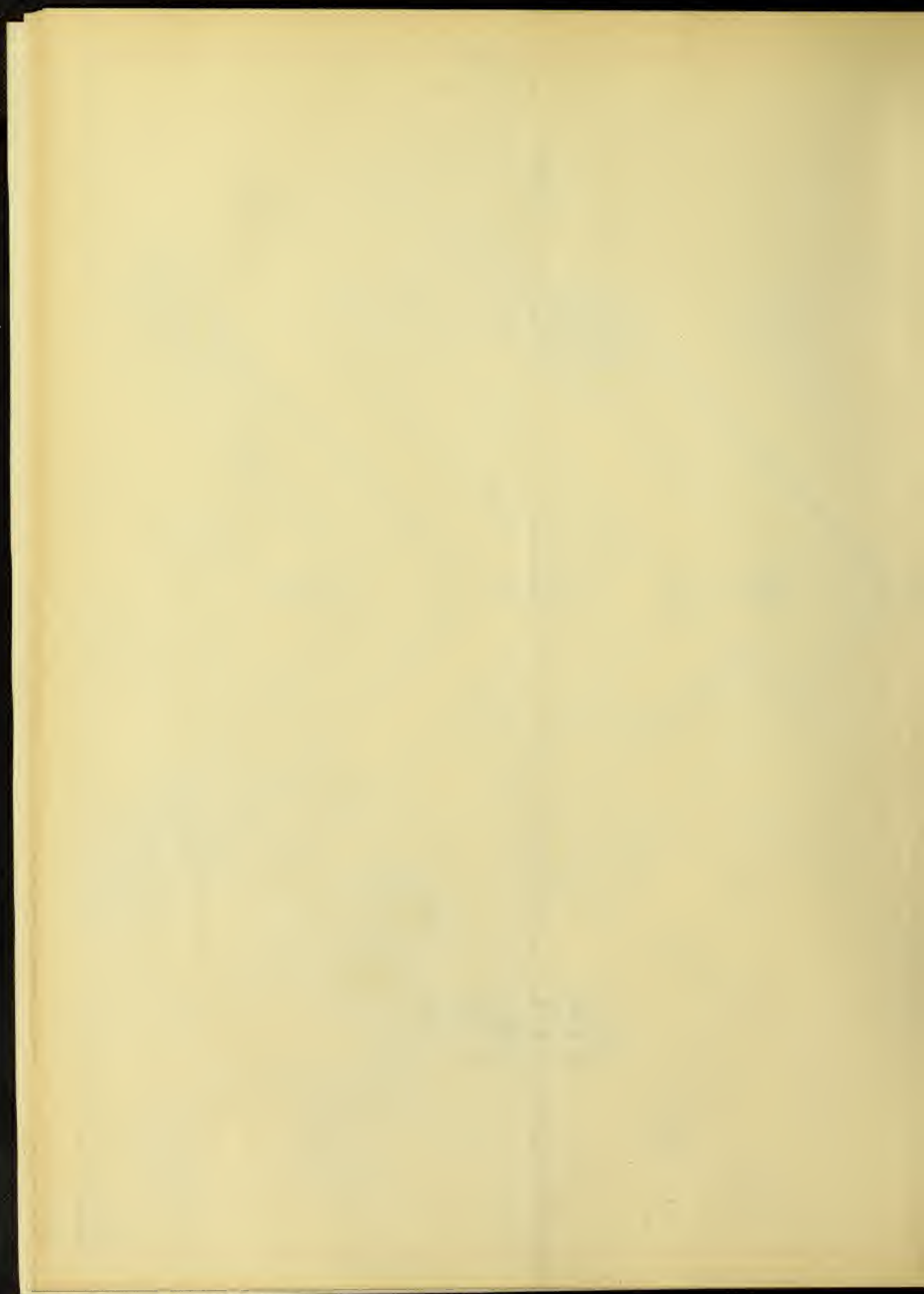
Scale - Half size

Thesis of Klotz and Miles





TEST PIECES
Scale - Half size
Thesis of Klotz and Miles



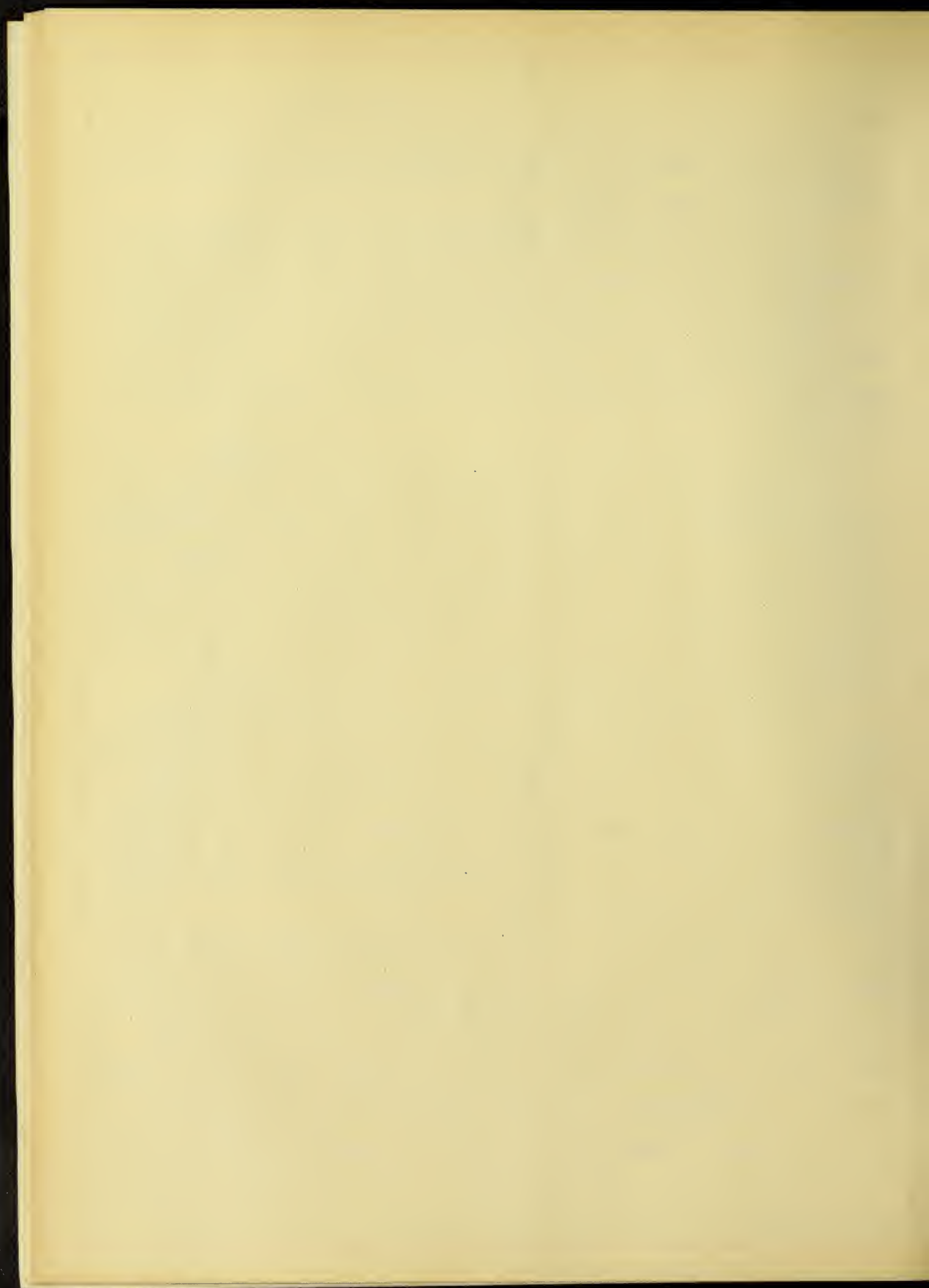
iron machine parts are required to withstand combined bending and tensile stress, especially when the bending stress is large in proportion to the direct stress.

It was believed that the curved beam theory of Bach could be applied to this specimen, and the results of the tests compared with those predicted both by this theory and by the straight beam theory in ordinary use. A brief treatment of Bach's theory and its application to this specimen will be included in the discussion of the results.

In order that test pieces might be secured which would be strictly accurate and which would meet the requirements, the writers themselves did the shop work involved. This consisted in making the patterns and core boxes, and in making the cores and setting up the molds in the foundry. All of this work was performed in the shops of the Mechanical Engineering Department of the University.

Realizing that the value of the results obtained would depend very largely upon the uniformity of the quality of iron in all specimens, it was the desire of the writers to have all the test pieces for the final tests cast from the same heat and, if possible, from the same run of iron. These conditions, however, were not obtained as will be explained later.

In setting up the molds the writers were very careful to treat every mold in as nearly the same manner as possible. All the ramming was done by one man who was careful to ram them all the same amount. As the castings for the preliminary tests did not peel as well as was desired, and as was necessary for securing the required accuracy in machining the pieces, a sea-coal facing was used on the molds for the test pieces used in the final series of tests. The pouring of the molds was superintended by the writers as a



further precaution.

The metal used was a rather better than average quality of grey iron, a large amount of scrap being used in the heats from which the pieces were poured. The quality of iron obtained from the different heats was essentially the same, care being taken by those in charge of the foundry to insure this fact. The castings were all well rattled to clean them and facilitate their handling in the machine shop. It was necessary to treat them all the same in this respect, as rattling is known to increase the strength of castings.

In the machine shop the holes were drilled for receiving the pins which held the eye bars used in gripping the pieces in the testing machine. These holes were carefully laid out so that the line of action of the applied force would be just four inches from the center of gravity of the filleted section. Not only was the exact location of these holes important, but it was also necessary that they be drilled parallel to the center line of the section through which the break was expected to occur. Care was taken in clamping the pieces to the drill table to see that this condition would be obtained. The pins and eye bars for holding the specimens in the testing machine were made of high carbon steel and were case-hardened. The hole in the eye bar was so drilled that the pin would be a snug fit in the test piece and have a slight amount of play in the eye bar.



III

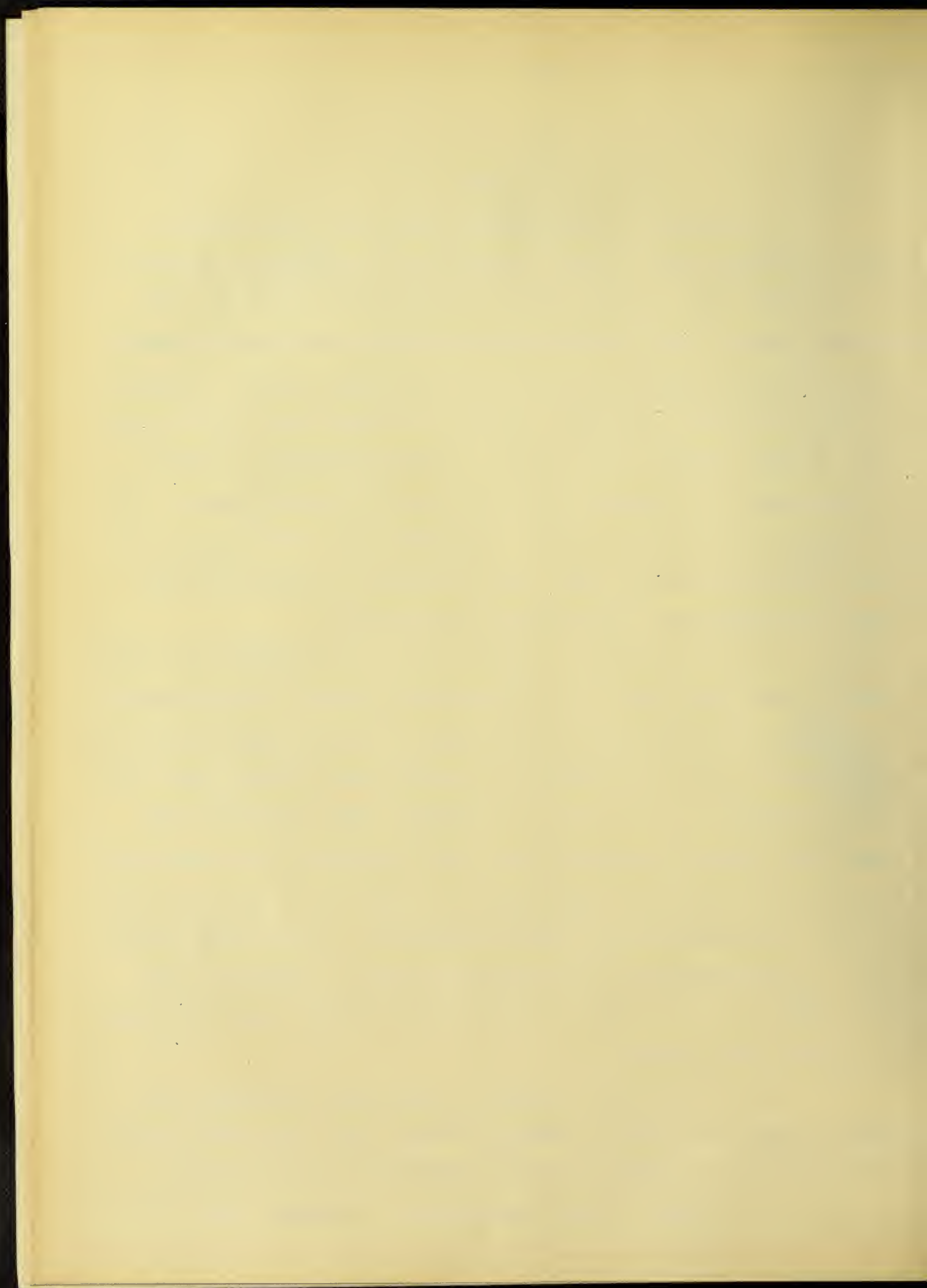
PRELIMINARY TESTS

As a means of obtaining some clue as to what results might be expected and to aid in mapping out the method of procedure for the final tests, a short series of preliminary tests was made. For these tests, four different sizes of fillets were used, namely, fillets of zero radius, i.e., a sharp corner, one-quarter, one-half, and one inch radii. The effort was made to secure two or more specimens of each size but, due to faulty molds or mishaps in pouring, only one each of the quarter and half inch radii were obtained. In this series the load was applied at a uniform rate till rupture occurred, only the breaking load being recorded, in addition to the manner of breaking and the nature of the fracture.

As to the manner of applying the load, it should be noted that the pins which held the eye bars were fitted in the specimens fairly tightly, while the fit of the pins in the eye bars was just sufficient to allow free turning of the bar about the pin. This reduced the friction of the pins to a minimum, thus preventing this source from causing any appreciable error by shifting the action line of the applied force and thus varying its moment arm. Care was taken to secure the pieces in the testing machine so that the line of pull would be perpendicular to the transverse plane of symmetry of the piece. This was essential in order that the required four inch moment arm would be secured.

In all the tests a Riehle, one hundred thousand pound, vertical, two-screw testing machine was used. The cross-head of the machine was run at a speed of about one-tenth inch per minute.

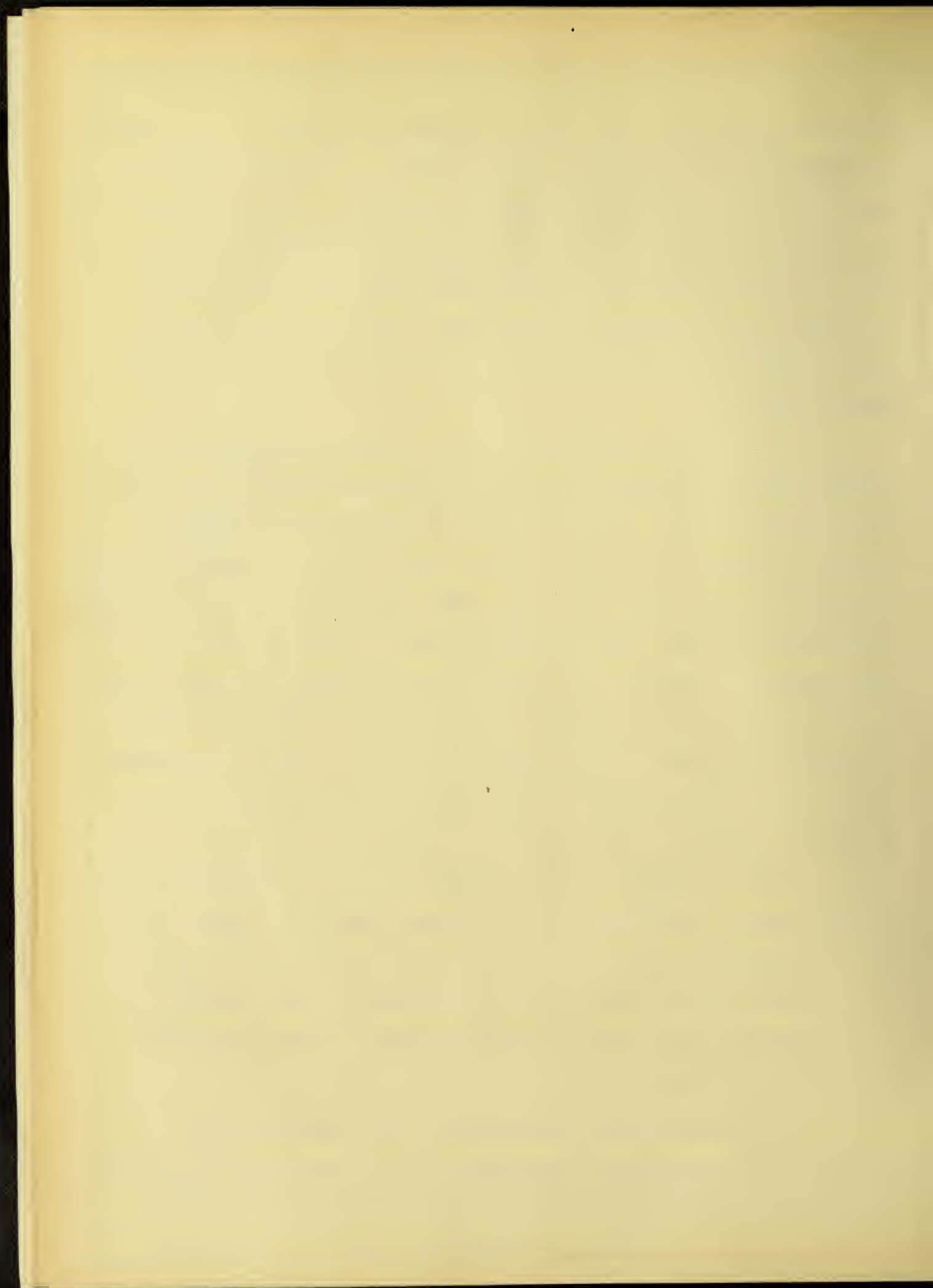
The results of these tests were, in general, what was ex-



pected, and indicated that further tests were warranted. In the case of the sharp cornered specimens and the one of one-quarter inch radius, the instant of breaking could be determined only by the dropping of the scale beam, so slow and quiet was the rupture. In the cases of the half inch and one inch radii the breaks were sudden, accompanied by loud reports. In all cases the line of fracture on both the inside and outside of the piece was a straight line of remarkable sharpness.

The feature which was strongly brought out by these preliminary tests and which was perhaps of greatest interest, was the fact that the specimen with the fillet of one-half inch radius was the last to break in the fillet itself. That is, in the sharp cornered and the quarter and half inch radii specimens, the line of fracture started from the inside corner or center of the fillet, and proceeded across the section, as shown in the drawings on the data sheet. But in the cases of the specimens having fillets of one inch radius, the fracture occurred in the straight part of the piece, approximately at the point of tangency of the fillet with the straight side of the piece. This result showed that the desirable size of fillet for a piece of these proportions was somewhere between one-half inch and one inch radius, since any further increase caused the break to occur in the straight part of the piece closer to the line of action of the applied force. Because of this discovery, it was decided to include specimens with fillets of five-eighths and three-quarters inch radii in the final tests.

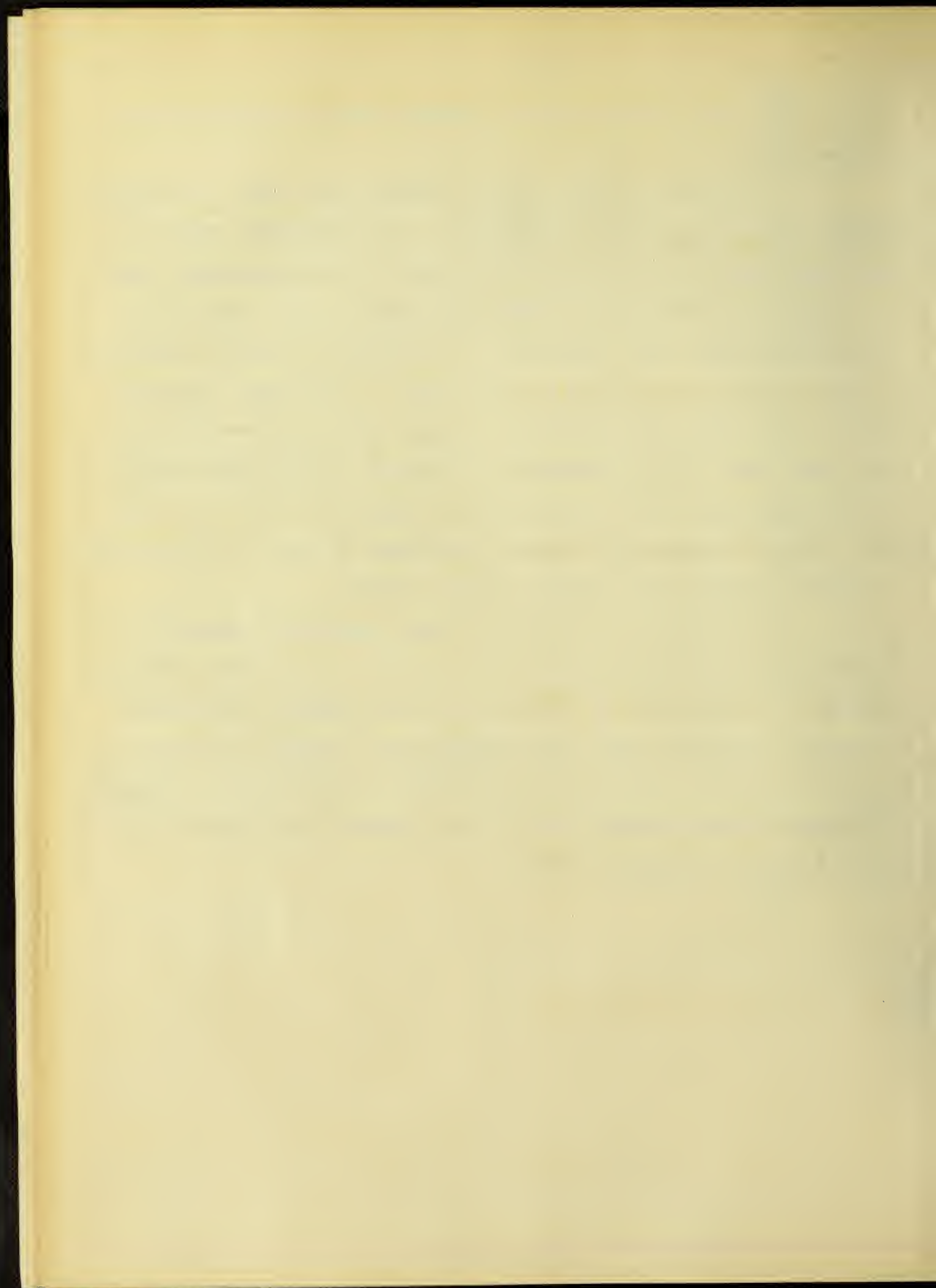
The results of the preliminary tests showed that the strength of the specimen was increased with each increase in the size of the fillet, although no definite relation between the strength



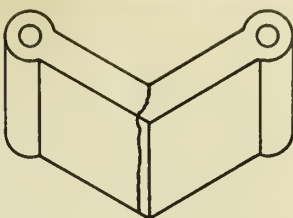
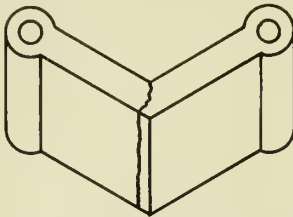
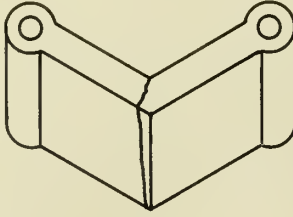
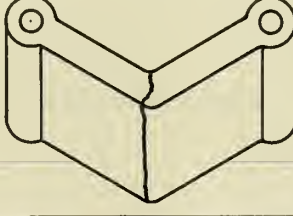
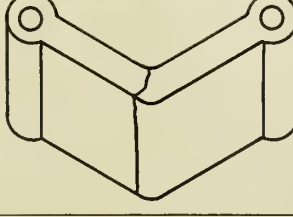
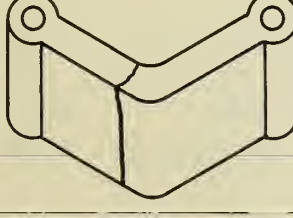
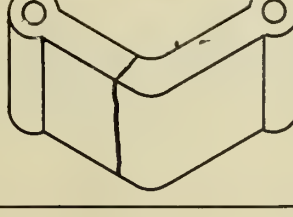
and the size of the fillet could be derived from the testing of so few specimens.

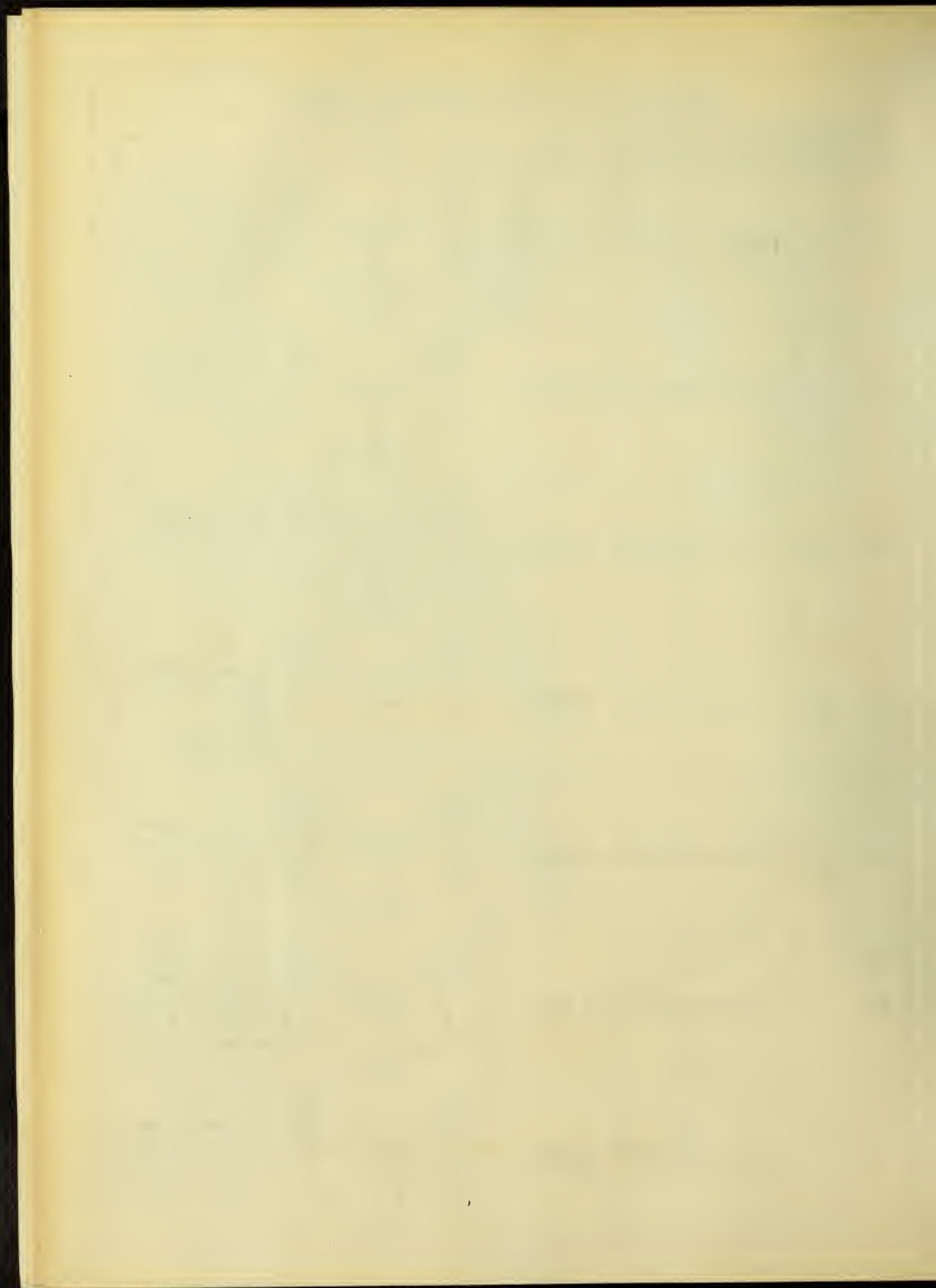
The quality of iron in the specimens was found to be quite uniform. One flaw appeared consistently in each specimen. This was a spongy spot which occurred in the same place in each specimen, namely, at about the middle of the depth and closer to the inside than to the outside edge. The reason for its occurrence is easily explained. The section at the corner is the largest in the piece, contains the most metal, and consequently is the last part of the casting to cool. This causes all the impurities to collect at this point forming the spongy mass. This condition may be expected in all cast iron under similar circumstances unless a riser can be put in at this point to obviate the difficulty at the time of casting.

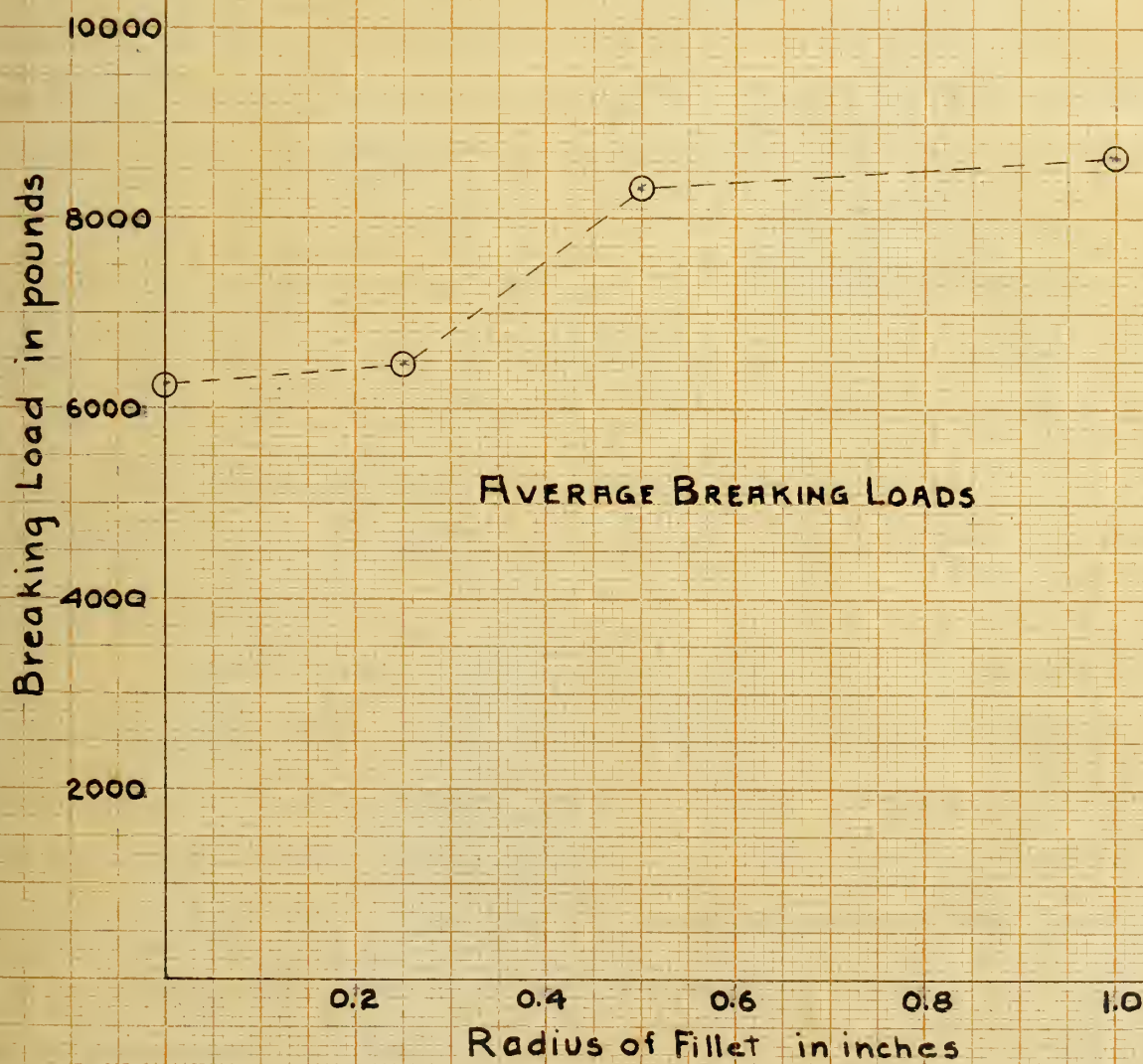
The effect of the fillets on the crystalline structure of the iron was distinctly shown at the fractures. In the sharp cornered specimens, the structure of the iron was very markedly flaky around the outside and inside edges and extending well toward the center of the section. As the fillets were introduced and their radii increased, this flaky structure became less and less apparent and the iron appeared more as a homogeneous mass.



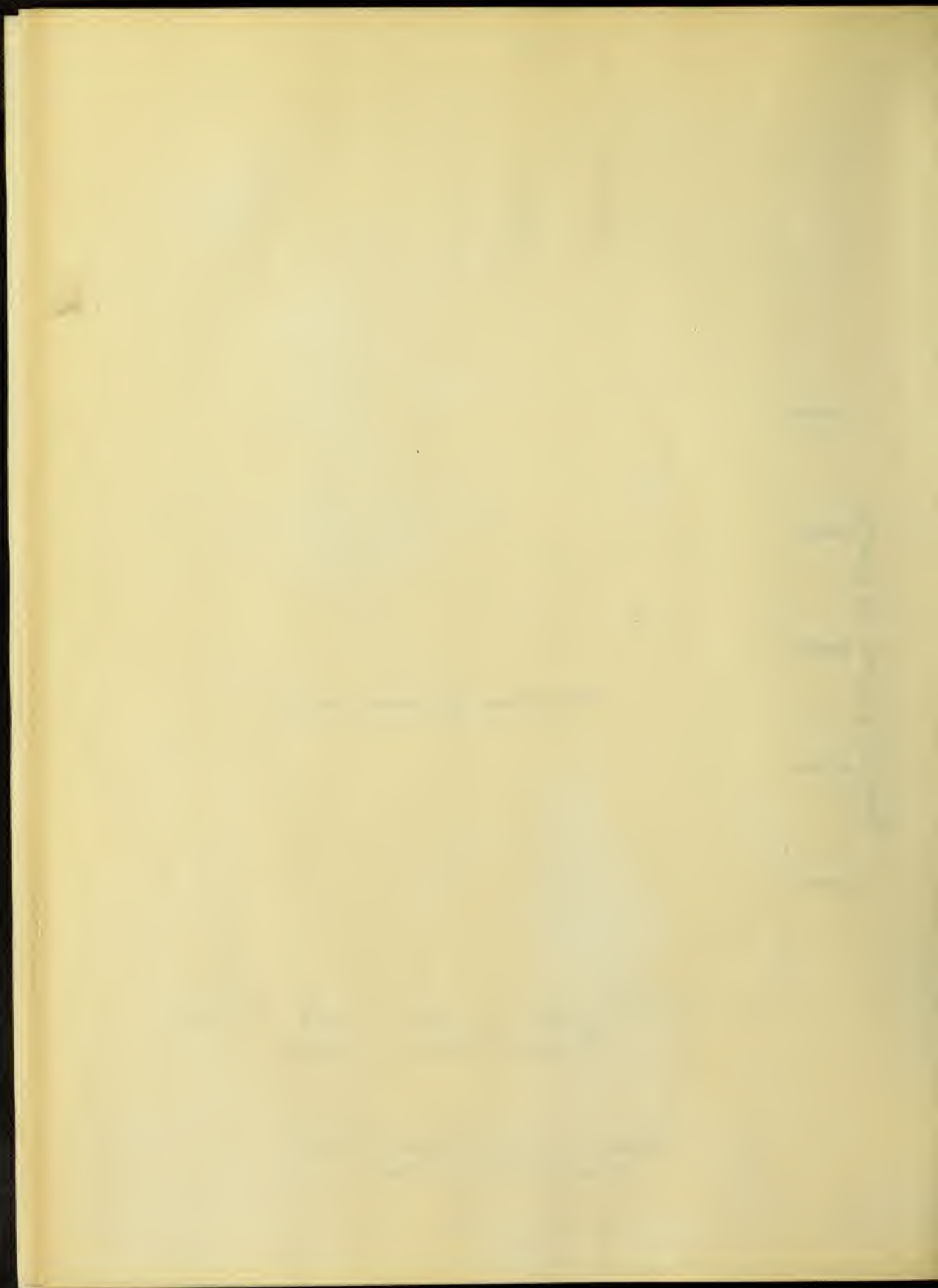
RESULTS OF PRELIMINARY TESTS

No.	Radius of Fillet	Thickness	Depth	Moment Arm	Breaking Load	Remarks
1	0	1.85"	4.00	4.00	7215	 Slow break No noise. Spongy spot at about center of depth and near inside edge.
2	0	1.77"	3.99	4.03	5720	 No noise to indicate failure of specimen. Usual spongy spot.
3	0	1.81"	4.00	4.00	5930	 Quiet break. Usual spongy spot
4	$\frac{1}{4}$ "	1.79"	3.97	4.09	6480	 Quiet break. Usual spongy spot. One small blowhole
5	$\frac{1}{2}$ "	1.80	3.98	4.09	8320	 Sudden break Moderate report. Usual spongy spot.
6	1"	1.78"	4.00	3.95	8510	 Sudden break. Distinct report. Spongy spot not evident. Rupture at point of tangency of inside radius.
7	1"	1.80	3.95	4.09	8800	 Loud report. No spongy spot. 2 small blowholes. Rupture through straight section.





RESULTS OF PRELIMINARY TESTS
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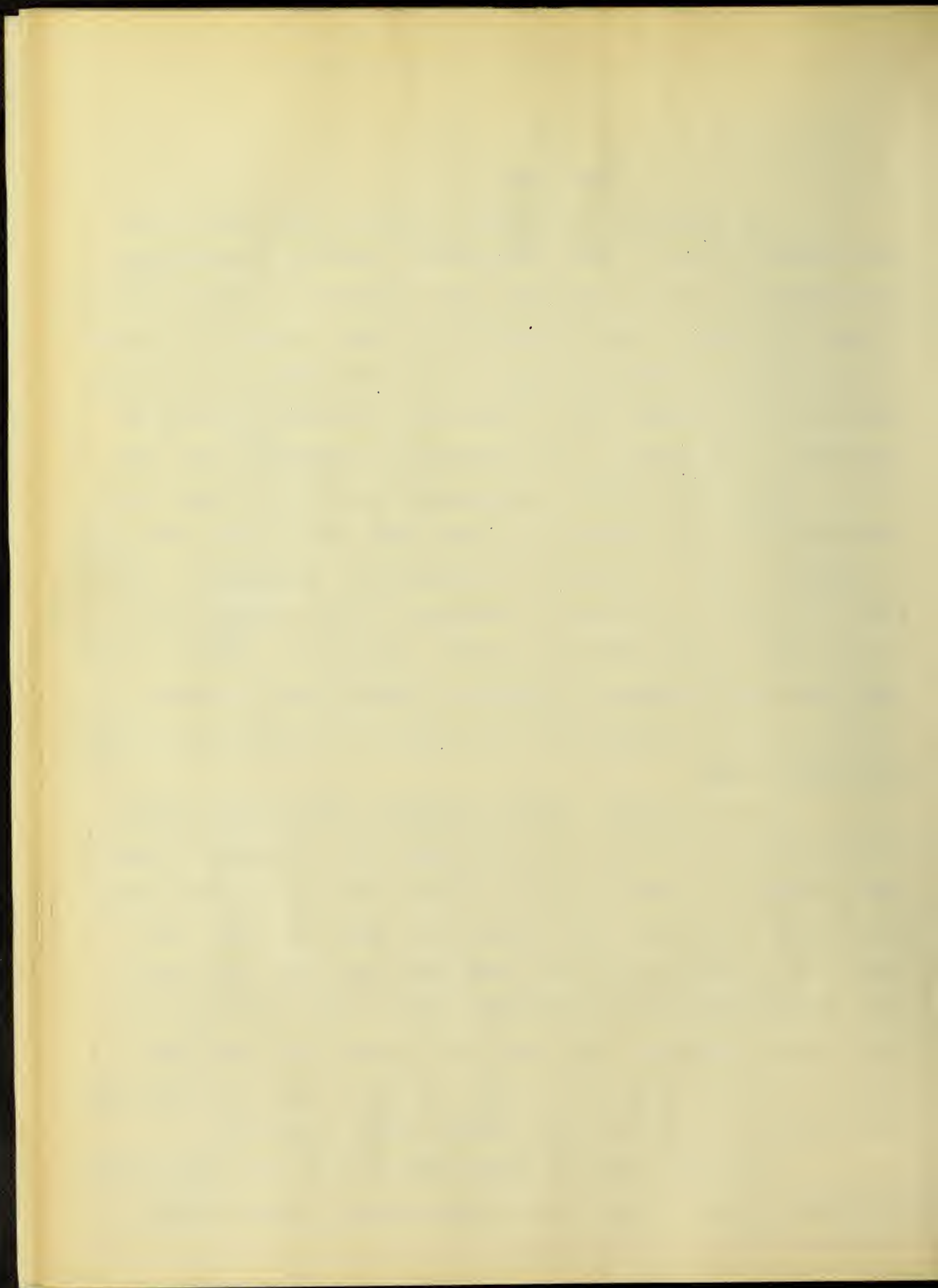
IV

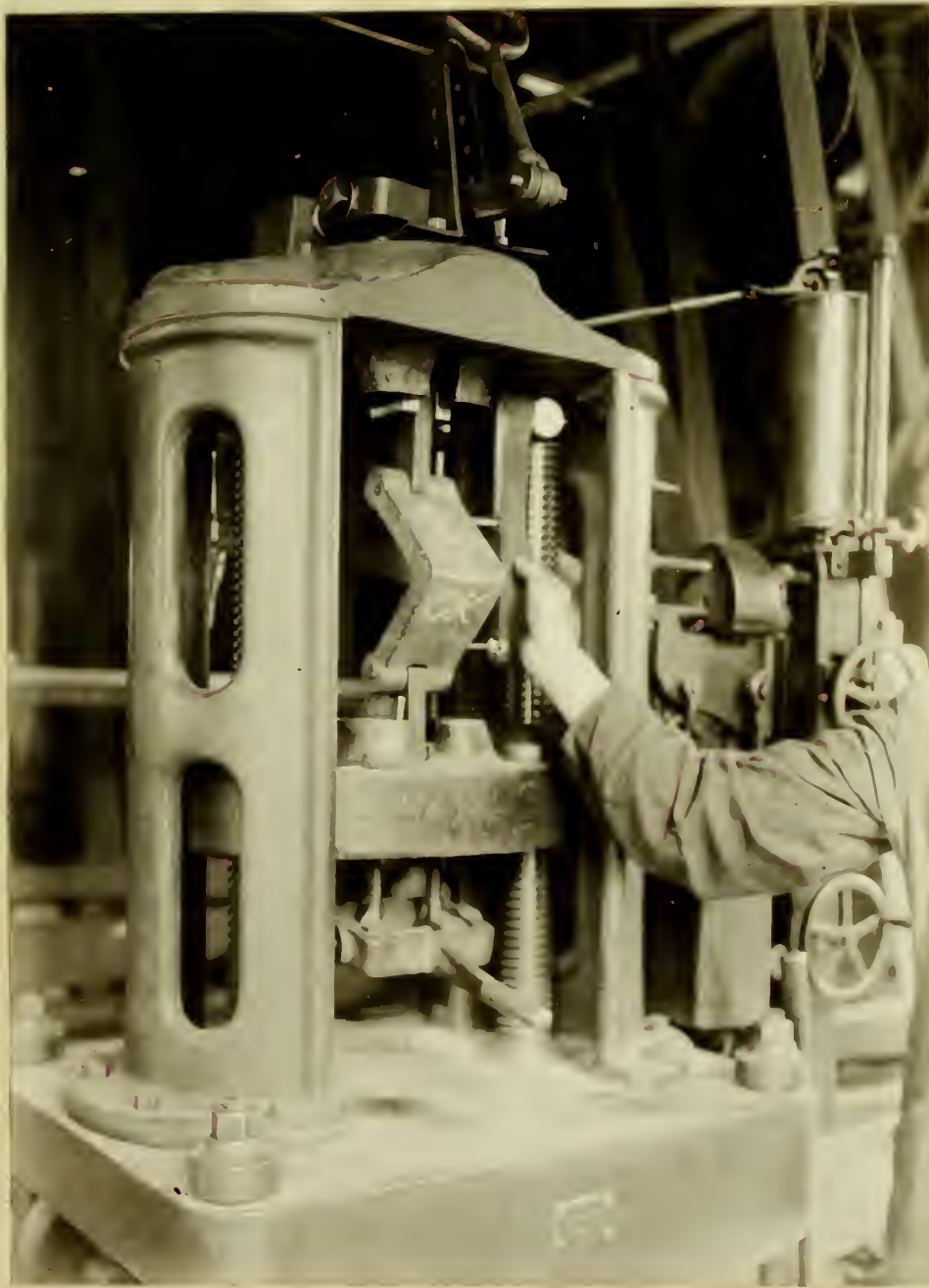
FINAL TESTS

The specimens for the final series of tests were of six sizes, having fillets of zero, one-quarter, one-half, five-eighths, three-quarters, and one inch radii. Four specimens of each size were tested, thus making a total of twenty-four tests. In two of the sizes it was possible to make five tests, due to a few extra castings being supplied. It was thought that it would be of interest to determine the effect of the fillets on the deflection of the pieces. For this purpose a Berry type removable extensometer was used. Two small holes were drilled in each specimen six inches apart and on a line parallel to the line of pull, to be used in attaching the extensometer to the piece. The load was increased by increments of five hundred pounds in some cases and one thousand in others, extensometer readings being taken after each increase. The manner of gripping the test pieces in the machine and of attaching the extensometer is clearly shown in the photograph on page

Due to defective castings resulting from the first heat, the test pieces were taken in all from four heats. The number of perfect castings from each heat was as follows: fourteen from the first, six from the second, and four from each the third and fourth. The quality of the iron in the first three heats was found not to vary much, if any, more than from different parts of the same heat. The iron from the fourth heat was softer, due to more pig being used instead of so much scrap. But the number of pieces taken from this heat was so small as not to influence average results seriously.

The results obtained agreed quite closely with those of the preliminary tests. As before, the sharp-cornered specimens failed





Photograph showing specimen in machine
and method of attaching extensometer.

Thesis of Klotz and Miles.

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noiselessly, while the breaking of the pieces with the one-quarter ^{inch} fillet was accompanied with a dull and scarcely audible snap. All the other specimens failed suddenly and with a loud report. The manner of failure of the sharp cornered specimens bears out the curved beam theory for curvatures of very small radius, that is, pieces bent at right angles on themselves. In pieces of this kind the neutral fiber passes through the inside edge of the sharp corner and, hence, no resistance to bending can be offered. Therefore, the slightest bending strain produces incipient rupture. Actually this condition does not exist because the stress distribution is so modified as to shift the neutral axis from its theoretical position. The character of the break, however, indicates that this condition is approached.

The variability of cast iron is clearly shown by the results obtained. In some cases the breaking load of two specimens of the same dimensions differed as much as two thousand pounds. The curve, page 44, plotted between the breaking loads and the radii of the fillets, shows graphically the effect of the increased radius of fillet on the strength of the piece. All but two of the sizes are seen to lie practically on a straight line. For the one-half inch radius the result is seen to be especially discordant, the variations in the loads at which the specimens of this size broke being unusually extreme. This was due to the exceptionally poor quality of the iron in the pieces of this size, blowholes of unusual size appearing in several of the specimens.

In the case of the fillet of five-eighths inch radius, the ideal condition of having all the specimens cast from the same heat, was obtained. As would consequently be expected, these specimens exhibited the least variation in breaking load between the



several pieces. Even in this case, a maximum variation of a trifle more than on thousand pounds was observed.

The use of the extensometer furnished some interesting results. The manner in which the general trend of the deflection in the various pieces coincides is strongly brought out by the deflection curves. It will be noticed that the graphs are typical for cast iron, being curves whose curvature increases as rupture is approached. This indicates that for even moderate loads cast iron does not closely follow Hook's law.

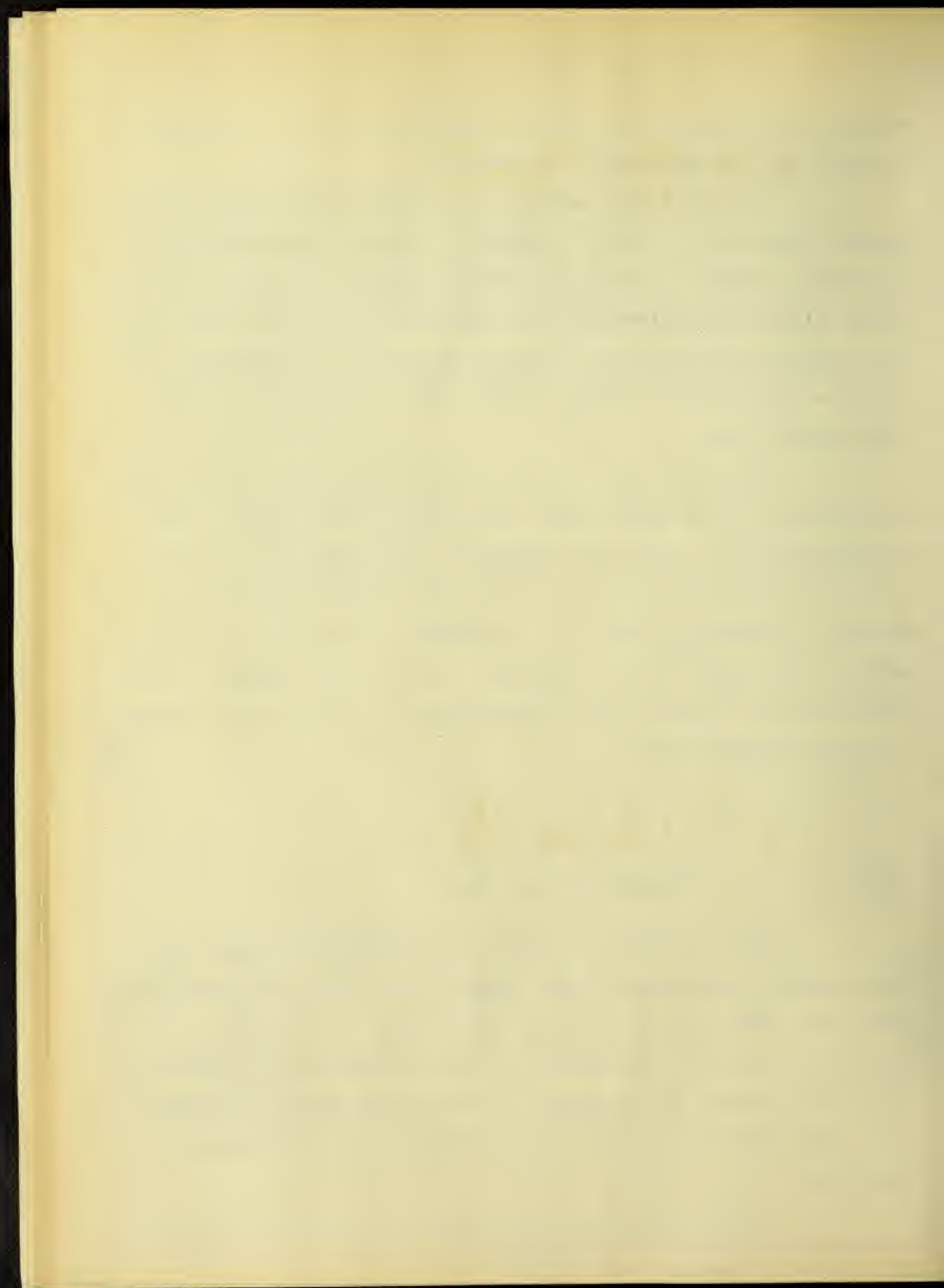
The curves plotted from the average deflections at various loads for the different radii show, as might be expected, that the deflection at a given load decreases as strength of the section is increased by increasing the radius of the fillet. Furthermore, the decrease in deflection due to the increased size of fillet is more marked at the higher loads. The quality of the iron accounts for the irregularities in these curves corresponding to those in the curves of average breaking loads.

V

THEORETICAL DISCUSSION

It was deemed of considerable interest to investigate this problem on the basis of the theory of the curved beam. For this purpose the "Theory of Stresses in Curved Bars" in Appendix A of Bulletin No. 18 of the University of Illinois Engineering Experiment Station was applied to the problem in hand. This theory is substantially that laid down by Bach in his "Elasticitat und Festigkeit", Article 54.

An expression for the intensity of stress at any point



of the section,

$$s = \frac{P}{f} + \frac{M_b}{f r} + \frac{M_b}{z f r} \times \frac{y}{r+y}$$

is obtained from this theory, in which,

P = the external force, in pounds, acting at right angles to the section

f = the area of the section in square inches

M_b = the moment of the couple acting at the section

The value of M_b is positive when it tends to increase the curvature of the bar, and negative when it tends to decrease its curvature.

y = the distance, in inches, from the neutral axis of the section to the point under consideration, and is positive when measured toward the convex side of the bar and negative when measured toward the concave side, that is, toward the center of curvature

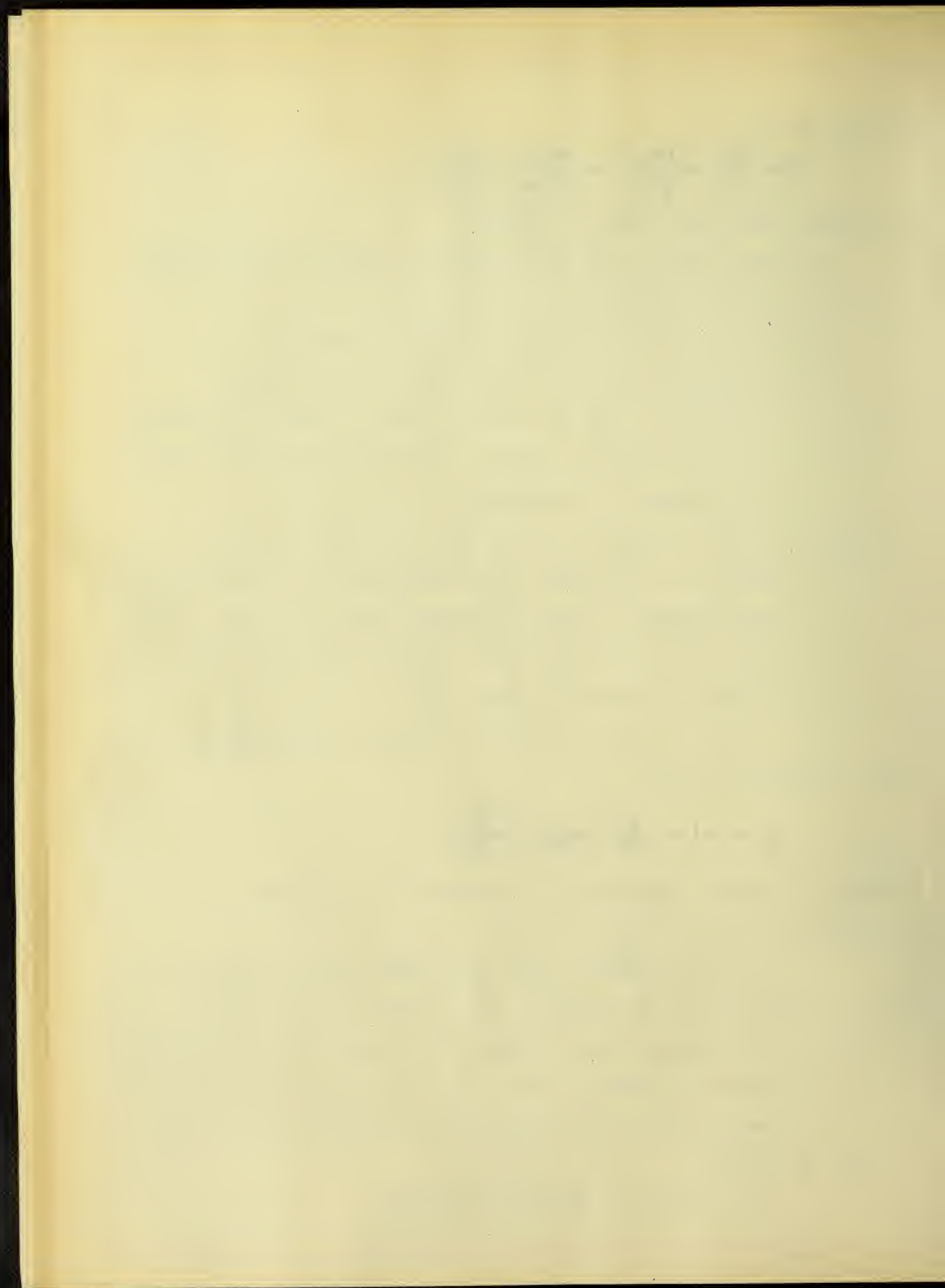
For a rectangular cross section of width " b " and depth " $2a$ ", according to Bach,

$$Z = -1 + \frac{r}{2a} \log_e \frac{1 + \frac{a}{r}}{1 - \frac{a}{r}}$$

in which " r " equals the radius of curvature of the neutral axis of the section.

It was discovered that this theory could be applied to only one radius of fillet, namely, the one inch, as the center of curvature of the neutral axis of each of the other radii fell within the section itself. Evidently, this makes the value of " a " greater than " r ", in which case it is impossible to evaluate " z " and hence to apply the theory.

For the fillet of one inch radius,



$$Z = -1 + \frac{1}{1.8} \log_e \frac{1+0.9}{1-0.9} = -1 + \frac{2.94}{1.8} = 0.632$$

In this case, $P = 9930$ lb., $M_b = -9930 \times 4 = -39720$ lb. in., and $y = -0.9$ in. Hence,

$$s = \frac{9930}{4 \times 1.8} - \frac{39720}{4 \times 1.8} - \frac{-39720}{0.632 \times 4 \times 1.8} \times \frac{-0.9}{1-0.9}$$

$$= 1380 - 5520 + 78500$$

$$= 74360 \text{ lb. per sq. in.}$$

As the modulus of rupture of cast iron in flexure is known to be in the neighborhood of 35000 lb. per sq. in., the extreme stress which is obtained above by the application of Bach's curved beam theory indicates that the pieces under investigation and the manner in which they were stressed, did not conform to the conditions upon which this theory is based.

For the purpose of comparison, the straight beam theory was also applied, which gives an expression for the maximum stress, "s", as follows:

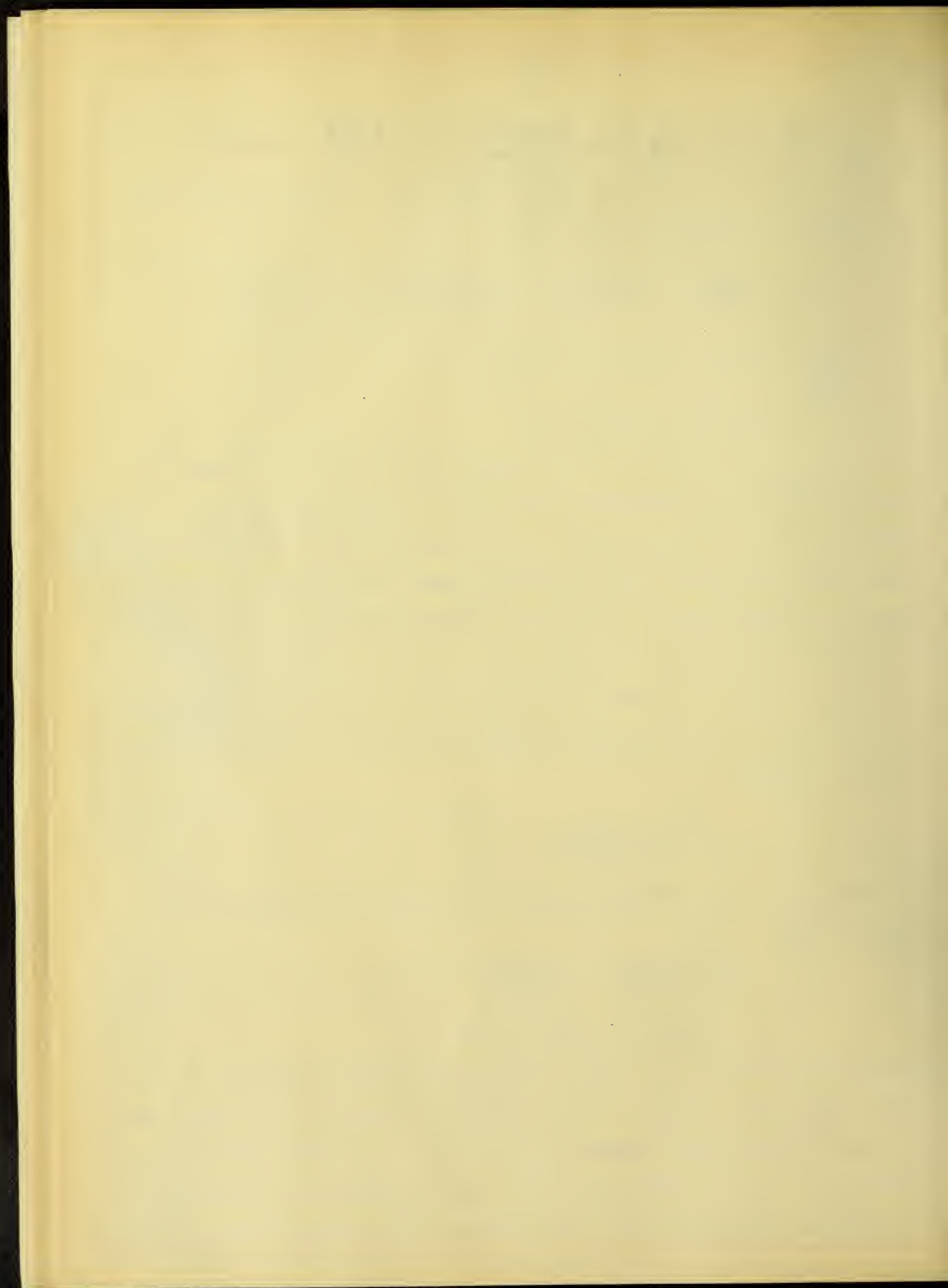
$$s = \frac{P}{f} + \frac{Mc}{I}$$

In the case of the one inch fillet, this expression gives for the value of "s":

$$s = \frac{9930}{7.2} + \frac{39720}{2.16}$$

$$= 19760 \text{ lb. per sq. in.}$$

This value is seen to be about half of the expected modulus of rupture. Hence, the results obtained from the applications of the curved beam and straight beam theories point to the conclusion that the conditions in this test place the piece under investigation somewhere between these two extremes. This conclusion is a logical one and the



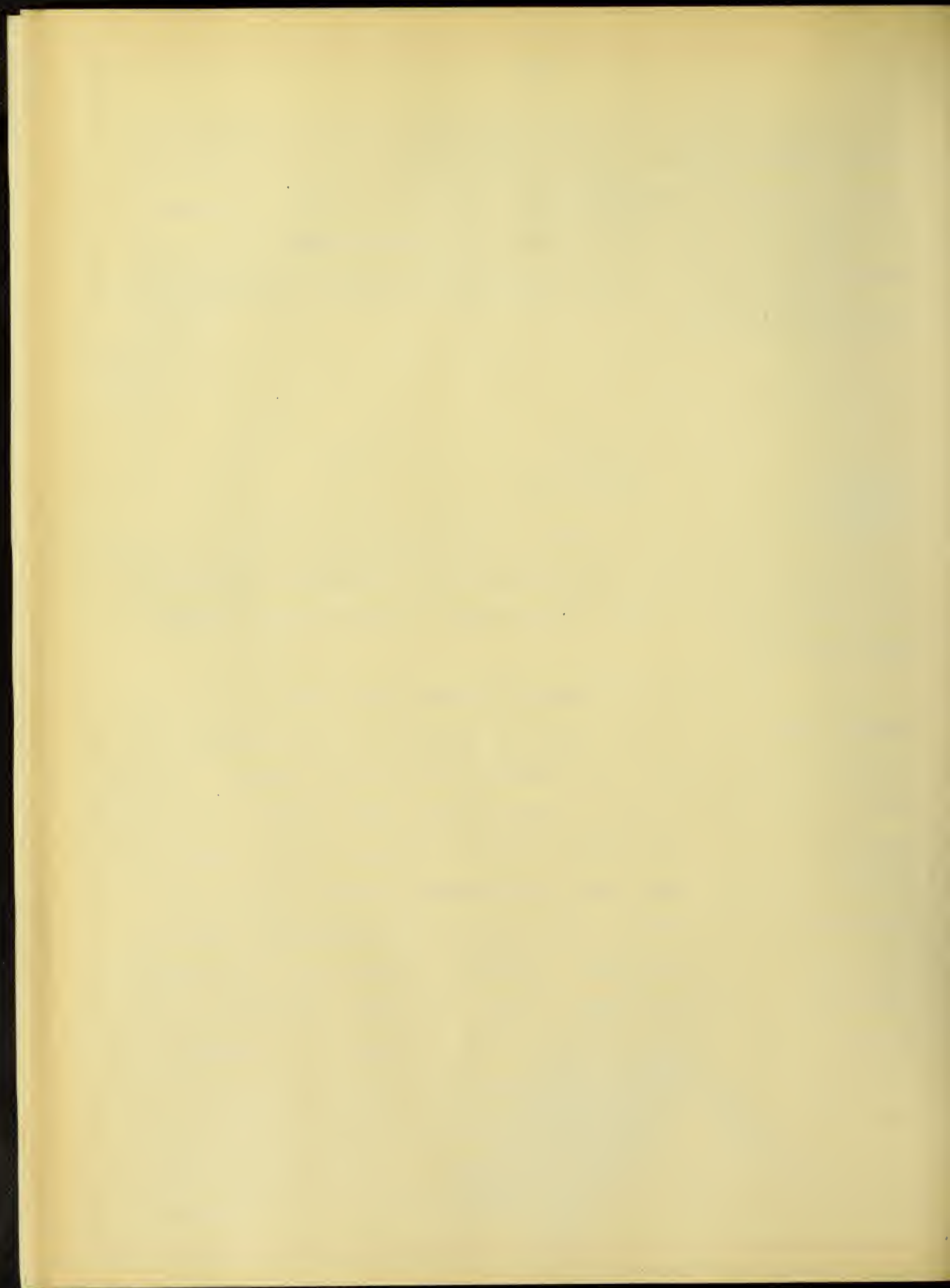
results obtained bear the relations to each other that might be expected, considering the peculiarities of the test piece which separate it distinctly from both the classes of straight and curved beams. The fact that cast iron does not follow Hooke's law even approximately accounts for the failure of the results obtained to substantiate the theory.

VI

CONCLUSIONS

As was stated before, the writers realize that the conclusions drawn from this investigation must be largely qualitative, as it was possible to test only one size of section with varying sizes of fillets.

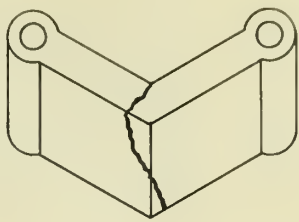
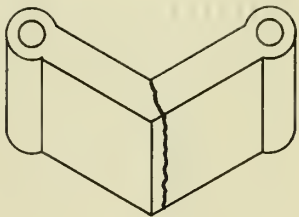
The curve of average breaking loads indicates that the maximum effect of the fillet was not reached and that a larger fillet would still increase the strength of the piece. However, the fact that the specimens with the one inch fillet broke through the straight part indicates that this size of fillet is large enough to make the filleted section stronger than the straight section. The size of fillet which will accomplish this result is the desirable size, beyond which it is not expedient to go. The desirable size lies between the fillets of three-quarters and one inch radius. Therefore, since the one inch size lies on the safe side, and since the thickness of the straight section is one and one-quarter inches, the ratio of the radius of the fillet to the thickness of the section is one to one and a quarter. In other words, the radius of fillet advisable for this type of piece may be taken as eight tenths of the thickness of

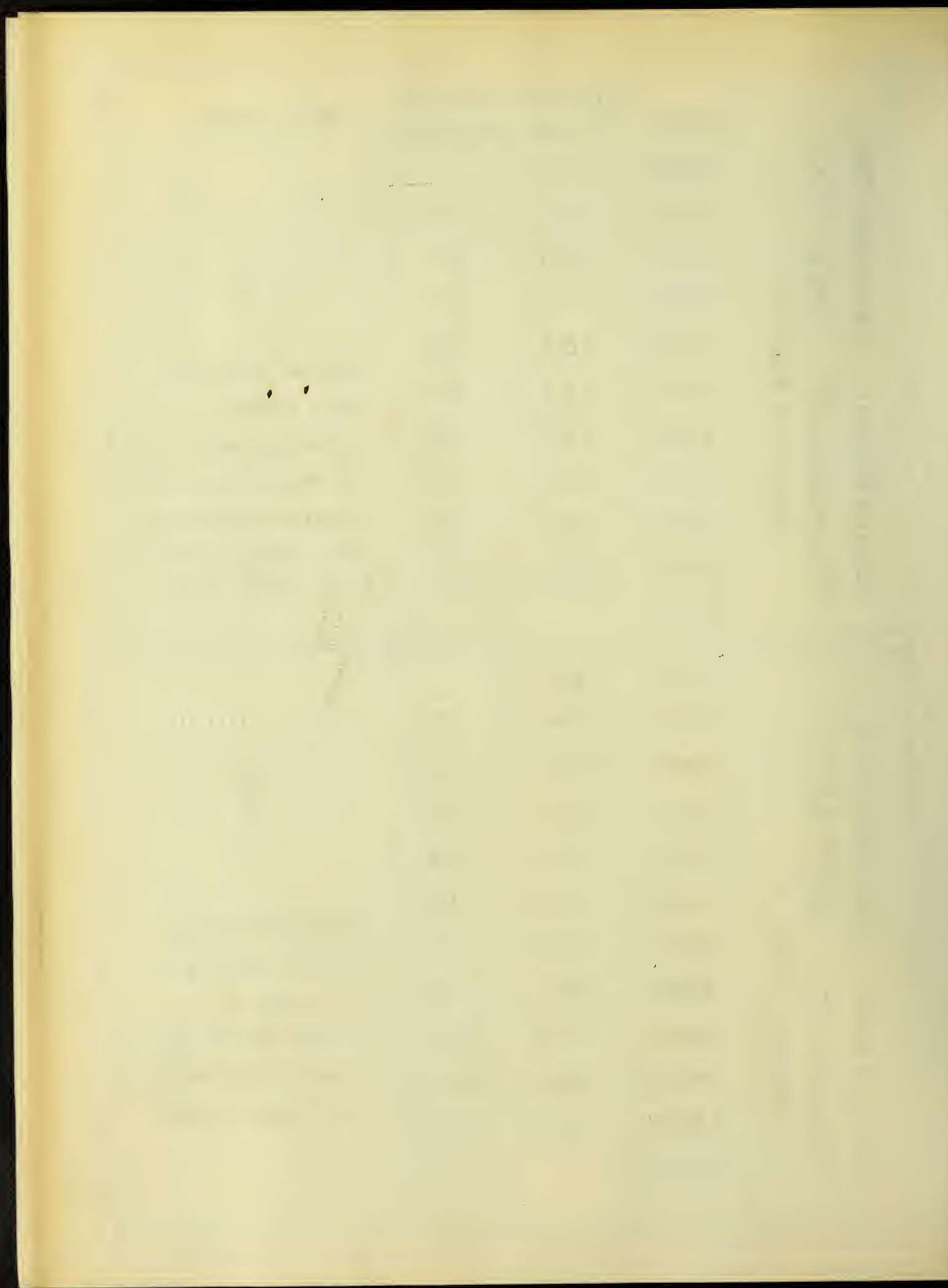


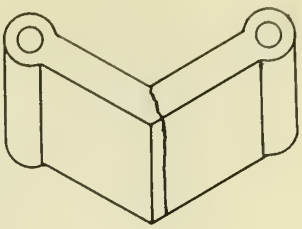
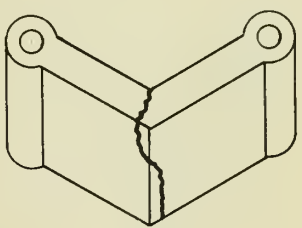
the section.

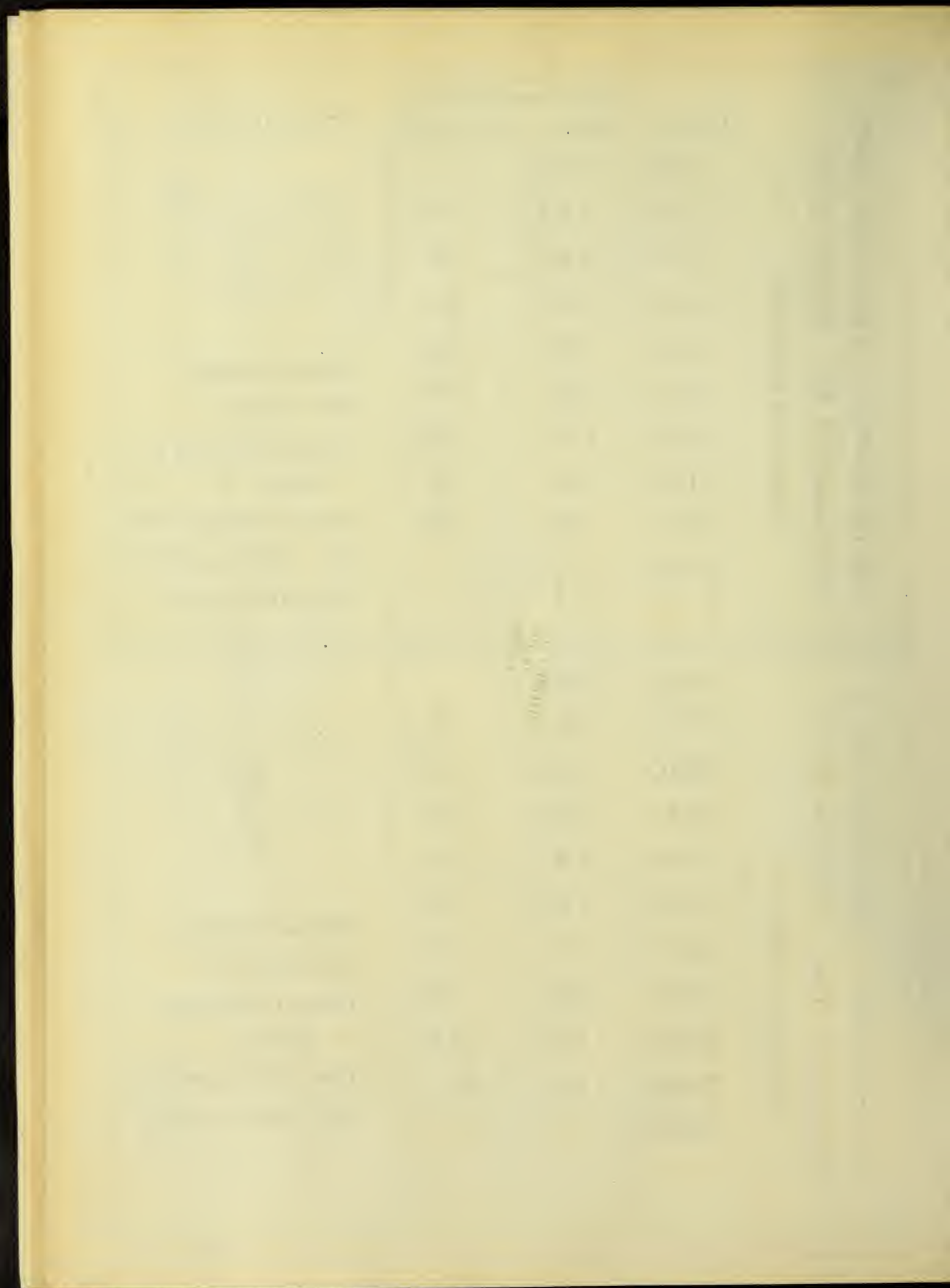
It is the belief of the writers that, with these results for guidance along the lines of an investigation of this nature, results could be obtained that would be a sufficient basis for quantitative conclusions. It is to be noted that the results of these tests can not be applied to pieces in which the curves of the outside and inside edges are concentric, thus making the piece of uniform thickness throughout. It would be of interest to test some specimens of this type.

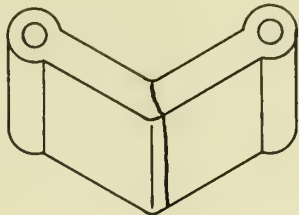
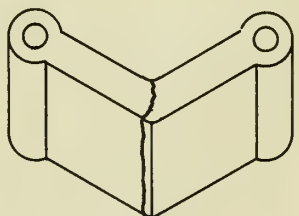
Date	Description	Amount		Balance
		Dr	Cr	
1890				
Jan 1	Balance			100.00
Jan 15	Wages	5.00		95.00
Jan 20	Food	2.50		92.50
Jan 25	Travel	1.00		91.50
Jan 30	Postage	.50		91.00
Feb 5	Wages	6.00		85.00
Feb 10	Food	3.00		82.00
Feb 15	Travel	1.50		80.50
Feb 20	Postage	.75		79.75
Feb 25	Wages	7.00		72.75
Feb 28	Food	3.50		69.25
Mar 5	Travel	2.00		67.25
Mar 10	Postage	.80		66.45
Mar 15	Wages	8.00		58.45
Mar 20	Food	4.00		54.45
Mar 25	Travel	2.50		51.95
Mar 30	Postage	1.00		50.95
Apr 5	Wages	9.00		41.95
Apr 10	Food	4.50		37.45
Apr 15	Travel	3.00		34.45
Apr 20	Postage	1.20		33.25
Apr 25	Wages	10.00		23.25
Apr 30	Food	5.00		18.25
May 5	Travel	3.50		14.75
May 10	Postage	1.50		13.25
May 15	Wages	11.00		2.25
May 20	Food	5.50		(3.25)
May 25	Travel	4.00		(7.25)
May 30	Postage	1.75		(9.00)
Jun 5	Wages	12.00		(21.00)
Jun 10	Food	6.00		(27.00)
Jun 15	Travel	4.50		(31.50)
Jun 20	Postage	2.00		(33.50)
Jun 25	Wages	13.00		(46.50)
Jun 30	Food	6.50		(53.00)
Jul 5	Travel	5.00		(58.00)
Jul 10	Postage	2.25		(60.25)
Jul 15	Wages	14.00		(74.25)
Jul 20	Food	7.00		(81.25)
Jul 25	Travel	5.50		(86.75)
Jul 30	Postage	2.50		(89.25)
Aug 5	Wages	15.00		(104.25)
Aug 10	Food	7.50		(111.75)
Aug 15	Travel	6.00		(117.75)
Aug 20	Postage	2.75		(120.50)
Aug 25	Wages	16.00		(136.50)
Aug 30	Food	8.00		(144.50)
Sep 5	Travel	6.50		(151.00)
Sep 10	Postage	3.00		(154.00)
Sep 15	Wages	17.00		(171.00)
Sep 20	Food	8.50		(179.50)
Sep 25	Travel	7.00		(186.50)
Sep 30	Postage	3.25		(189.75)
Oct 5	Wages	18.00		(207.75)
Oct 10	Food	9.00		(216.75)
Oct 15	Travel	7.50		(224.25)
Oct 20	Postage	3.50		(227.75)
Oct 25	Wages	19.00		(246.75)
Oct 30	Food	9.50		(256.25)
Nov 5	Travel	8.00		(264.25)
Nov 10	Postage	3.75		(268.00)
Nov 15	Wages	20.00		(288.00)
Nov 20	Food	10.00		(298.00)
Nov 25	Travel	8.50		(306.50)
Nov 30	Postage	4.00		(310.50)
Dec 5	Wages	21.00		(331.50)
Dec 10	Food	10.50		(342.00)
Dec 15	Travel	9.00		(351.00)
Dec 20	Postage	4.25		(355.25)
Dec 25	Wages	22.00		(377.25)
Dec 30	Food	11.00		(388.25)
Total				

Sharp Corner Specimen No.1 Thickness 1.80" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	390	314		 Slow break No noise Spongy spot $1 \times \frac{5}{8}$" at middle of depth near inside edge For total deflection add .006"
	1100	292	22	
	1500	283	31	
	2000	277	37	
	2500	268	46	
	3070	253	61	
	3950	228	86	
	5010	205	109	
	5590	187	127	
	5980	176	138	
	6380			
Sharp Corner Specimen No.2 Thickness 1.81" Depth 3.93" Moment Arm 4"	200	463		 Slight snap Usual spongy spot Blow hole $1\frac{3}{8} \times \frac{1}{2}$" For total deflection add 0.004"
	660	456	7	
	1040	448	15	
	1530	437	26	
	2000	429	34	
	2540	415	48	
	3020	404	59	
	3500	391	72	
	4000	375	88	
	4620	356	107	
	4850	322	141	
	4920			

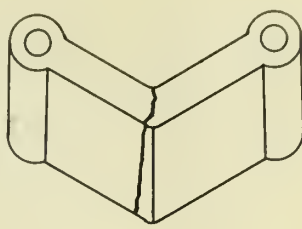
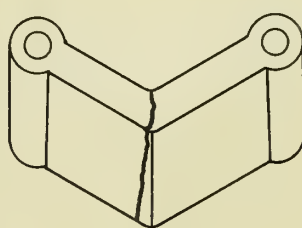


Sharp Corner Specimen No. 4 Thickness 1.81" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	700	234		 Slow break No noise Usual spongy spot Small blow hole For total deflection add 0.012"
	1050	227	7	
	1500	216	18	
	2000	207	27	
	2500	196	38	
	3000	185	49	
	3520	175	59	
	4130	163	71	
	4920	136	98	
	5320			
Sharp Corner Specimen No. 5 Thickness 1.80" Depth 3.93" Moment Arm 4"	400	276		 Slow break No noise Usual spongy spot For total deflection add 0.006"
	1000	264	12	
	1500	225	21	
	2050	248	28	
	2590	234	42	
	3040	226	50	
	3575	217	59	
	4110	204	72	
	5040	178	98	
	5340	155	111	
	5600			

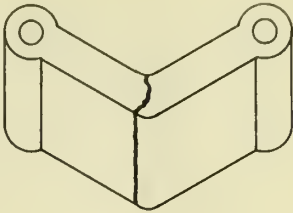
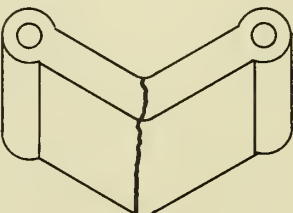


$\frac{1}{4}$ " Radius Specimen No. 2 Thickness 1.81" Depth 3.94" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	500	287		 Sudden break Usual spongy spot $\frac{3}{8}$" $\times$ $\frac{3}{8}$" blowhole For total deflection add 0.008"
	1080	271	16	
	1550	263	24	
	2080	255	32	
	2500	245	42	
	3000	237	50	
	3500	224	63	
	4130	210	77	
	4620	203	84	
	5160	184	103	
	5740			
$\frac{1}{4}$ " Radius Specimen No. 1 Thickness 1.82" Depth 3.96" Moment Arm 4"	550	150		 Sudden break Usual spongy spot For total deflection add 0.008"
	1000	143	7	
	1500	134	16	
	2050	125	25	
	2500	118	32	
	3000	111	39	
	3500	100	50	
	4130	85	65	
	5050	68	82	
	5950	45	105	
	6780	18	132	
	6830			

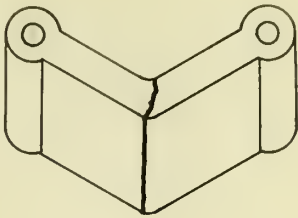
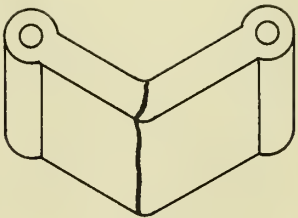
Name		Age		Sex		Religion		Marital Status		Occupation		Education		Income		Assets		Liabilities		Net Worth	
John Doe		35		Male		Protestant		Married		Teacher		High School		\$12,000		\$5,000		\$7,000		\$10,000	
Jane Smith		28		Female		Catholic		Single		Nurse		College		\$8,000		\$2,000		\$6,000		\$8,000	
Robert Johnson		42		Male		Jewish		Married		Engineer		University		\$15,000		\$8,000		\$7,000		\$10,000	
Mary White		30		Female		Muslim		Single		Doctor		Medical School		\$20,000		\$10,000		\$10,000		\$10,000	
David Brown		25		Male		Hindu		Single		Student		High School		\$5,000		\$1,000		\$4,000		\$5,000	
Susan Green		38		Female		Buddhist		Married		Artist		Art School		\$10,000		\$3,000		\$7,000		\$8,000	
Michael Black		45		Male		Atheist		Married		Lawyer		Law School		\$18,000		\$12,000		\$6,000		\$12,000	
Emily Taylor		22		Female		Sikh		Single		Teacher		College		\$6,000		\$1,500		\$4,500		\$6,000	
Christopher Lee		33		Male		Jewish		Married		Engineer		University		\$14,000		\$7,000		\$7,000		\$10,000	
Amanda Hall		27		Female		Catholic		Single		Nurse		College		\$9,000		\$2,500		\$6,500		\$9,000	
Daniel King		40		Male		Protestant		Married		Teacher		High School		\$11,000		\$4,000		\$7,000		\$10,000	
Nicole Adams		31		Female		Muslim		Single		Doctor		Medical School		\$19,000		\$9,000		\$10,000		\$10,000	
Kevin Baker		24		Male		Hindu		Single		Student		High School		\$5,500		\$1,200		\$4,300		\$5,500	
Rachel Clark		36		Female		Buddhist		Married		Artist		Art School		\$10,500		\$3,500		\$7,000		\$8,500	
Gregory Evans		43		Male		Atheist		Married		Lawyer		Law School		\$17,500		\$11,500		\$6,000		\$11,500	
Victoria Harris		21		Female		Sikh		Single		Teacher		College		\$6,500		\$1,800		\$4,700		\$6,500	
Benjamin Scott		34		Male		Jewish		Married		Engineer		University		\$13,500		\$6,500		\$7,000		\$10,000	
Stephanie Young		26		Female		Catholic		Single		Nurse		College		\$8,500		\$2,800		\$5,700		\$8,500	
Timothy Allen		41		Male		Protestant		Married		Teacher		High School		\$11,500		\$4,500		\$7,000		\$10,000	
Christina King		29		Female		Muslim		Single		Doctor		Medical School		\$18,500		\$8,500		\$10,000		\$10,000	
Nathan Wright		23		Male		Hindu		Single		Student		High School		\$5,800		\$1,300		\$4,500		\$5,800	
Olivia Lopez		37		Female		Buddhist		Married		Artist		Art School		\$10,800		\$3,800		\$7,000		\$8,800	
Jonathan Hill		44		Male		Atheist		Married		Lawyer		Law School		\$17,800		\$11,800		\$6,000		\$11,800	
Sophia Green		20		Female		Sikh		Single		Teacher		College		\$6,800		\$1,900		\$4,900		\$6,800	
Ethan White		32		Male		Jewish		Married		Engineer		University		\$13,800		\$6,800		\$7,000		\$10,000	
Mia Black		25		Female		Catholic		Single		Nurse		College		\$8,800		\$2,900		\$5,900		\$8,800	
Liam Brown		40		Male		Protestant		Married		Teacher		High School		\$11,800		\$4,800		\$7,000		\$10,000	
Isabella Taylor		28		Female		Muslim		Single		Doctor		Medical School		\$19,200		\$9,200		\$10,000		\$10,000	
Noah Clark		22		Male		Hindu		Single		Student		High School		\$5,900		\$1,400		\$4,500		\$5,900	
Ava Evans		35		Female		Buddhist		Married		Artist		Art School		\$10,900		\$3,900		\$7,000		\$8,900	
Caleb Harris		43		Male		Atheist		Married		Lawyer		Law School		\$17,900		\$11,900		\$6,000		\$11,900	
Charlotte King		21		Female		Sikh		Single		Teacher		College		\$6,900		\$2,000		\$4,900		\$6,900	
Elijah Scott		33		Male		Jewish		Married		Engineer		University		\$13,900		\$6,900		\$7,000		\$10,000	
Amelia Young		26		Female		Catholic		Single		Nurse		College		\$8,900		\$3,000		\$5,900		\$8,900	
Isaac Allen		41		Male		Protestant		Married		Teacher		High School		\$11,900		\$4,900		\$7,000		\$10,000	
Grace King		29		Female		Muslim		Single		Doctor		Medical School		\$19,300		\$9,300		\$10,000		\$10,000	
Nathan Wright		23		Male		Hindu		Single		Student		High School		\$6,000		\$1,500		\$4,500		\$6,000	
Olivia Lopez		37		Female		Buddhist		Married		Artist		Art School		\$11,000		\$4,000		\$7,000		\$9,000	
Jonathan Hill		44		Male		Atheist		Married		Lawyer		Law School		\$18,000		\$12,000		\$6,000		\$12,000	
Sophia Green		20		Female		Sikh		Single		Teacher		College		\$7,000		\$2,100		\$4,900		\$7,000	
Ethan White		32		Male		Jewish		Married		Engineer		University		\$14,000		\$7,000		\$7,000		\$10,000	
Mia Black		25		Female		Catholic		Single		Nurse		College		\$8,800		\$2,900		\$5,900		\$8,800	
Liam Brown		40		Male		Protestant		Married		Teacher		High School		\$11,800		\$4,800		\$7,000		\$10,000	
Isabella Taylor		28		Female		Muslim		Single		Doctor		Medical School		\$19,200		\$9,200		\$10,000		\$10,000	
Noah Clark		22		Male		Hindu		Single		Student		High School		\$5,900		\$1,400		\$4,500		\$5,900	
Ava Evans		35		Female		Buddhist		Married		Artist		Art School		\$10,900		\$3,900		\$7,000		\$8,900	
Caleb Harris		43		Male		Atheist		Married		Lawyer		Law School		\$17,900		\$11,900		\$6,000		\$11,900	
Charlotte King		21		Female		Sikh		Single		Teacher		College		\$6,900		\$2,000		\$4,900		\$6,900	
Elijah Scott		33		Male		Jewish		Married		Engineer		University		\$13,900		\$6,900		\$7,000		\$10,000	
Amelia Young		26		Female		Catholic		Single		Nurse		College		\$8,900		\$3,000		\$5,900		\$8,900	
Isaac Allen		41		Male		Protestant		Married		Teacher		High School		\$11,900		\$4,900		\$7,000		\$10,000	
Grace King		29		Female		Muslim		Single		Doctor		Medical School		\$19,300		\$9,300		\$10,000		\$10,000	
Nathan Wright		23		Male		Hindu		Single		Student		High School		\$6,000		\$1,500		\$4,500		\$6,000	
Olivia Lopez		37		Female		Buddhist		Married		Artist		Art School		\$11,000		\$4,000		\$7,000		\$9,000	
Jonathan Hill		44		Male		Atheist		Married		Lawyer		Law School		\$18,000		\$12,000		\$6,000		\$12,000	
Sophia Green		20		Female		Sikh		Single		Teacher		College		\$7,000		\$2,100		\$4,900		\$7,000	
Ethan White		32		Male		Jewish		Married		Engineer		University		\$14,000		\$7,000		\$7,000		\$10,000	
Mia Black		25		Female		Catholic		Single		Nurse		College		\$8,800		\$2,900		\$5,900		\$8,800	
Liam Brown		40		Male		Protestant		Married		Teacher		High School		\$11,800		\$4,800		\$7,000		\$10,000	
Isabella Taylor		28		Female		Muslim		Single		Doctor		Medical School		\$19,200		\$9,200		\$10,000		\$10,000	
Noah Clark		22		Male		Hindu		Single		Student		High School		\$5,900		\$1,400		\$4,500		\$5,900	
Ava Evans		35		Female		Buddhist		Married		Artist		Art School		\$10,900		\$3,900		\$7,000		\$8,900	
Caleb Harris		43		Male		Atheist		Married		Lawyer		Law School		\$17,900		\$11,900		\$6,000		\$11,900	
Charlotte King		21		Female		Sikh		Single		Teacher		College		\$6,900		\$2,000		\$4,900		\$6,900	
Elijah Scott		33		Male		Jewish		Married		Engineer		University		\$13,900		\$6,900		\$7,000		\$10,000	
Amelia Young		26		Female		Catholic		Single		Nurse		College		\$8,900		\$3,000		\$5,900		\$8,900	
Isaac Allen		41		Male		Protestant		Married		Teacher		High School		\$11,900		\$4,900		\$7,000		\$10,000	
Grace King		29		Female		Muslim		Single		Doctor		Medical School		\$19,300		\$9,300		\$10,000		\$10,000	
Nathan Wright		23		Male		Hindu		Single		Student		High School		\$6,000		\$1,500		\$4,500		\$6,000	
Olivia Lopez		37		Female		Buddhist		Married		Artist		Art School		\$11,000		\$4,000		\$7,000		\$9,000	
Jonathan Hill		44		Male		Atheist		Married		Lawyer		Law School		\$18,000		\$12,000		\$6,000		\$12,000	
Sophia Green		20		Female		Sikh		Single		Teacher		College		\$7,000		\$2,100		\$4,900		\$7,000	
Ethan White		32		Male		Jewish		Married		Engineer		University		\$14,000		\$7,000		\$7,000		\$10,000	
Mia Black		25		Female		Catholic		Single		Nurse		College		\$8,800		\$2,900		\$5,900		\$8,800	
Liam Brown		40		Male		Protestant		Married		Teacher		High School		\$11,800		\$4,800		\$7,000		\$10,000	
Isabella Taylor		28		Female		Muslim		Single		Doctor		Medical School		\$19,200		\$9,200		\$10,000		\$10,000	
Noah Clark		22		Male		Hindu		Single		Student		High School		\$5,900		\$1,400		\$4,500		\$5,900	
Ava Evans		35		Female		Buddhist		Married		Artist		Art School		\$10,900		\$3,900		\$7,000		\$8,900	
Caleb Harris		43		Male		Atheist		Married		Lawyer		Law School		\$17,900		\$11,900		\$6,000		\$11,900	
Charlotte King		21		Female		Sikh		Single		Teacher		College		\$6,900		\$2,000		\$4,900		\$6,900	
Elijah Scott		33		Male		Jewish		Married		Engineer		University		\$13,900		\$6,900		\$7,000		\$10,000	
Amelia Young		26		Female		Catholic		Single		Nurse		College		\$8,900		\$3,000		\$5,900		\$8,900	
Isaac Allen		41		Male		Protestant		Married		Teacher		High School		\$11,900		\$4,900		\$7,000		\$10,000	
Grace King		29		Female		Muslim		Single		Doctor		Medical School		\$19,300		\$9,300		\$10,000		\$10,000	
Nathan Wright		23		Male		Hindu		Single		Student		High School		\$6,000		\$1,500		\$4,500		\$6,000	
Olivia Lopez		37		Female		Buddhist		Married		Artist		Art School		\$11,000		\$4,000		\$7,000		\$9,000	
Jonathan Hill		44		Male		Atheist		Married		Lawyer		Law School		\$18,000		\$12,000		\$6,000		\$12,000	
Sophia Green		20		Female		Sikh		Single		Teacher		College		\$7,000		\$2,100		\$4,900		\$7,000	
Ethan White		32		Male		Jewish		Married		Engineer		University		\$14,000		\$7,000		\$7,000		\$10,000	
Mia Black		25		Female		Catholic		Single		Nurse		College		\$8,800		\$2,900		\$5,900		\$8,800	
Liam Brown		40		Male		Protestant		Married		Teacher		High School		\$11,800		\$4,800		\$7,000		\$10,000	
Isabella Taylor		28		Female		Muslim		Single		Doctor		Medical School		\$19,200		\$9,200		\$10,000		\$10,000	
Noah Clark		22		Male		Hindu		Single		Student		High School		\$5,900		\$1,400		\$4,500		\$5,900	
Ava Evans		35		Female		Buddhist		Married		Artist		Art School		\$10,900		\$3,900		\$7,000		\$8,900	
Caleb Harris		43		Male		Atheist		Married		Lawyer		Law School		\$17,900		\$11,900		\$6,000		\$11,900	
Charlotte King		21		Female		Sikh		Single		Teacher		College		\$6,900		\$2,000		\$4,900		\$6,900	
Elijah Scott		33		Male		Jewish		Married		Engineer		University		\$13,900		\$6,900		\$7,000		\$10,000	
Amelia Young		26		Female		Catholic		Single		Nurse											

$\frac{1}{4}$ " Radius Specimen No. 4 Thickness 1.84" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	510	178		 Sudden break. No noise. Usual spongy spot. $\frac{1}{4}$" blowhole For total deflect- -ion add 0.008"
	1000	169	9	
	1500	159	19	
	2000	151	27	
	2500	142	36	
	3000	134	44	
	4000	112	66	
	4600	99	79	
	5330	79	99	
	6000	45	133	
	6100			
$\frac{1}{4}$ " Radius Specimen No. 3 Thickness 1.80" Depth 3.93" Moment Arm 4"	630	260		 Sudden break Slight report Good metal ex- cept spongy spot For total deflect- -ion add 0.01"
	1050	250	10	
	1500	241	19	
	2070	231	29	
	2500	223	37	
	3000	211	49	
	3500	202	58	
	4150	188	72	
	4610	177	83	
	5230	166	94	
	5970	144	116	
	7390			

1900		1901	
Jan 1	100.00	100.00	100.00
Feb 1	100.00	100.00	100.00
Mar 1	100.00	100.00	100.00
Apr 1	100.00	100.00	100.00
May 1	100.00	100.00	100.00
Jun 1	100.00	100.00	100.00
Jul 1	100.00	100.00	100.00
Aug 1	100.00	100.00	100.00
Sep 1	100.00	100.00	100.00
Oct 1	100.00	100.00	100.00
Nov 1	100.00	100.00	100.00
Dec 1	100.00	100.00	100.00
Jan 1	100.00	100.00	100.00
Feb 1	100.00	100.00	100.00
Mar 1	100.00	100.00	100.00
Apr 1	100.00	100.00	100.00
May 1	100.00	100.00	100.00
Jun 1	100.00	100.00	100.00
Jul 1	100.00	100.00	100.00
Aug 1	100.00	100.00	100.00
Sep 1	100.00	100.00	100.00
Oct 1	100.00	100.00	100.00
Nov 1	100.00	100.00	100.00
Dec 1	100.00	100.00	100.00
Jan 1	100.00	100.00	100.00
Feb 1	100.00	100.00	100.00
Mar 1	100.00	100.00	100.00
Apr 1	100.00	100.00	100.00
May 1	100.00	100.00	100.00
Jun 1	100.00	100.00	100.00
Jul 1	100.00	100.00	100.00
Aug 1	100.00	100.00	100.00
Sep 1	100.00	100.00	100.00
Oct 1	100.00	100.00	100.00
Nov 1	100.00	100.00	100.00
Dec 1	100.00	100.00	100.00

$\frac{1}{2}$ " Radius Specimen No.2 Thickness 1.80" Depth 3.96" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	580	468		 Slow break, no report. Softer iron, smaller spongy spot. $\frac{1}{2}$" blowhole For total deflection add 0.012"
	1000	460	8	
	1500	450	18	
	2000	438	30	
	3000	417	51	
	4220	386	82	
	5000	366	102	
	5760	342	126	
	6370	318	150	
	7090	294	174	
	7800			
$\frac{1}{2}$ " Radius Specimen No.4 Thickness 1.77" Depth 4.00" Moment Arm 4"	560	334		 Dull report Usual spongy spot. $1\frac{1}{2} \times \frac{1}{4}$" blowhole. For total deflection add 0.01"
	1000	326	8	
	1500	315	19	
	2000	305	29	
	2500	293	41	
	3000	282	52	
	3500	268	66	
	4000	254	80	
	4500	241	93	
	5000	229	105	
	5500	205	129	
	5880			

Date	Description	Debit	Credit	Balance
1890				
Jan 1	Balance			100.00
Jan 10	Wages	5.00		95.00
Jan 20	Food	3.00		92.00
Jan 30	Travel	10.00		82.00
Feb 10	Wages	5.00		77.00
Feb 20	Food	3.00		74.00
Feb 30	Travel	10.00		64.00
Mar 10	Wages	5.00		59.00
Mar 20	Food	3.00		56.00
Mar 30	Travel	10.00		46.00
Apr 10	Wages	5.00		41.00
Apr 20	Food	3.00		38.00
Apr 30	Travel	10.00		28.00
May 10	Wages	5.00		23.00
May 20	Food	3.00		20.00
May 30	Travel	10.00		10.00
Jun 10	Wages	5.00		5.00
Jun 20	Food	3.00		2.00
Jun 30	Travel	10.00		(8.00)
Jul 10	Wages	5.00		(13.00)
Jul 20	Food	3.00		(16.00)
Jul 30	Travel	10.00		(26.00)
Aug 10	Wages	5.00		(31.00)
Aug 20	Food	3.00		(34.00)
Aug 30	Travel	10.00		(44.00)
Sep 10	Wages	5.00		(49.00)
Sep 20	Food	3.00		(52.00)
Sep 30	Travel	10.00		(62.00)
Oct 10	Wages	5.00		(67.00)
Oct 20	Food	3.00		(70.00)
Oct 30	Travel	10.00		(80.00)
Nov 10	Wages	5.00		(85.00)
Nov 20	Food	3.00		(88.00)
Nov 30	Travel	10.00		(98.00)
Dec 10	Wages	5.00		(103.00)
Dec 20	Food	3.00		(106.00)
Dec 30	Travel	10.00		(116.00)
Total		100.00		(116.00)

$\frac{1}{2}$ Radius Specimen No. 3 Thickness 1.79" Depth 3.96" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	450	240		 Dull report Usual spongy spot. $\frac{3}{8}$" x $\frac{1}{8}$" blow-hole. For total deflection add 0.008"
	1000	227	13	
	1500	217	23	
	2000	210	30	
	2500	200	40	
	3500	178	62	
	4200	166	74	
	5080	146	94	
	5770	122	118	
	6700	88	152	
	6970			
$\frac{1}{2}$ Radius Specimen No. 5 Thickness 1.82" Depth 3.96" Moment Arm 4"	550	249		 Sharp report Smaller spongy spot For total deflection add 0.01"
	1000	239	10	
	1500	230	19	
	2100	218	31	
	2600	209	40	
	3000	201	48	
	3500	191	58	
	4000	180	69	
	4600	168	81	
	5200	154	95	
	5940	136	113	
	7000	106	143	
	7100			

1. The first part of the paper is devoted to a general discussion of the problem. It is shown that the problem is of great importance in the theory of the structure of the atom.

2. In the second part of the paper, the author gives a detailed account of the experimental work which has been done in this field. It is shown that the results of these experiments are in good agreement with the theoretical predictions.

3. The third part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

4. The fourth part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

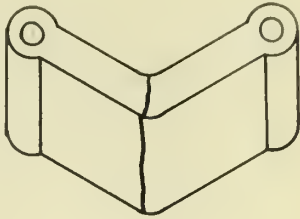
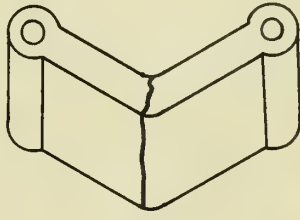
5. The fifth part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

6. The sixth part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

7. The seventh part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

8. The eighth part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

9. The ninth part of the paper is devoted to a discussion of the results of the experiments. It is shown that the results are in good agreement with the theoretical predictions.

$\frac{5}{8}$ " Radius Specimen No. 2 Thickness 1.74" Depth 3.95" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	500	381		 Sharp report Size of spongy spot reduced. $\frac{1}{2} \times \frac{3}{8}$" blow hole For total deflection add 0.01"
	1000	374	7	
	1500	363	18	
	2000	355	26	
	2500	344	37	
	3500	324	57	
	4400	305	76	
	5230	287	94	
	5810	269	112	
	6910	241	140	
	7620			
$\frac{5}{8}$ " Radius Specimen No. 1 Thickness 1.71" Depth 4.00" Moment Arm 4"	490	223		 Sharp report Spongy spot not so evident. $\frac{3}{8}$" blowhole For total deflection add 0.01"
	1000	215	8	
	1500	207	16	
	2000	195	28	
	2500	188	35	
	3000	177	46	
	3500	167	56	
	4980	134	89	
	5660	116	107	
	6230	100	123	
	6890	77	146	
	7760	48	175	
	7990			

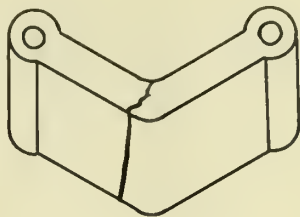
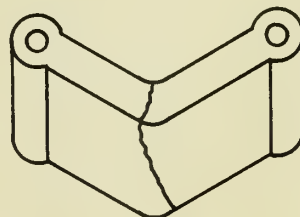
$\frac{5}{8}$ " Radius Specimen No. 4 Thickness 1.71" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	620	238		 No report, poor metal. Blowholes $1 \times \frac{1}{4}$" and $1 \frac{1}{4} \times \frac{3}{8}$". For total deflection add 0.011"
	1110	228	10	
	1500	221	17	
	2000	212	26	
	3000	190	48	
	4000	165	73	
	5000	140	98	
	5960	111	127	
	7740			
$\frac{5}{8}$ " Radius Specimen No. 3 Thickness 1.72" Depth 4.00" Moment Arm 4"	460	349		 Sharp report No blowholes Spongy spot barely noticeable. For total deflection add 0.01"
	1000	340	9	
	1500	332	17	
	2000	324	25	
	2500	315	34	
	3000	305	44	
	3500	296	53	
	4500	274	75	
	5690	249	100	
	6630	228	121	
	7300	208	141	
	8300	180	169	
	8660			

TABLE I

Summary of the results of the experiments on the effect of the concentration of the solution on the rate of the reaction.

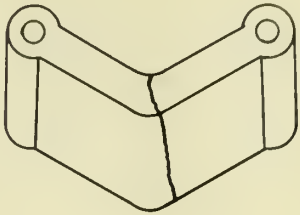
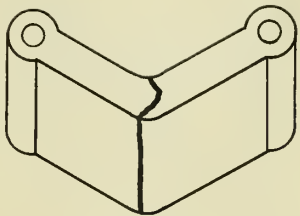
Concentration of the solution	Rate of the reaction	Time taken for completion
0.1 M	0.001	1000
0.2 M	0.002	500
0.3 M	0.003	333
0.4 M	0.004	250
0.5 M	0.005	200
0.6 M	0.006	167
0.7 M	0.007	143
0.8 M	0.008	125
0.9 M	0.009	111
1.0 M	0.010	100

continued on next page

Summary of the results of the experiments on the effect of the temperature on the rate of the reaction.

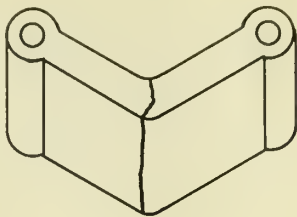
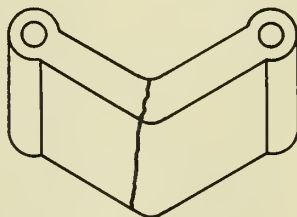
Temperature	Rate of the reaction	Time taken for completion
20°C	0.001	1000
25°C	0.002	500
30°C	0.004	250
35°C	0.008	125
40°C	0.016	62.5
45°C	0.032	31.25
50°C	0.064	15.625
55°C	0.128	7.8125
60°C	0.256	3.90625
65°C	0.512	1.953125
70°C	1.024	0.9765625

Summary of the results of the experiments on the effect of the catalyst on the rate of the reaction.

$\frac{3}{4}$ " Radius Specimen No. 3 Thickness 1.74 Depth 3.95" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	500	422		 Very sudden break $\frac{5}{8} \times \frac{3}{8}$ in the usual spongy spot. For total deflec- tion add 0.007"
	1000	413	9	
	2000	397	25	
	3000	378	44	
	4000	359	63	
	5070	338	84	
	6300	309	113	
	7100	282	140	
	8020	254	168	
	8090			
$\frac{3}{4}$ " Radius Specimen No. 2 Thickness 1.82" Depth 4.00" Moment Arm 4"	580	251		 Sudden break. Sharp report. $\frac{1}{2} \times \frac{5}{8}$ blowhole in the usual spongy spot. For total deflec- tion add 0.007"
	1000	242	9	
	2000	228	23	
	3000	210	41	
	4300	191	60	
	5140	173	78	
	6320	149	102	
	7300	126	125	
	8460			

1900		1901	
Jan	1.00	1.00	1.00
Feb	1.00	1.00	1.00
Mar	1.00	1.00	1.00
Apr	1.00	1.00	1.00
May	1.00	1.00	1.00
Jun	1.00	1.00	1.00
Jul	1.00	1.00	1.00
Aug	1.00	1.00	1.00
Sep	1.00	1.00	1.00
Oct	1.00	1.00	1.00
Nov	1.00	1.00	1.00
Dec	1.00	1.00	1.00

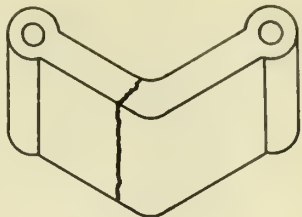
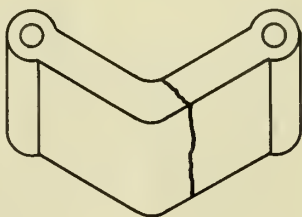
1902		1903	
Jan	1.00	1.00	1.00
Feb	1.00	1.00	1.00
Mar	1.00	1.00	1.00
Apr	1.00	1.00	1.00
May	1.00	1.00	1.00
Jun	1.00	1.00	1.00
Jul	1.00	1.00	1.00
Aug	1.00	1.00	1.00
Sep	1.00	1.00	1.00
Oct	1.00	1.00	1.00
Nov	1.00	1.00	1.00
Dec	1.00	1.00	1.00

$\frac{3}{4}$ " Radius Specimen No. 1 Thickness 1.80" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	500	320		 Sudden break. Good metal. Spongy spot reduced in size. For total deflection add 0.008"
	1000	313	7	
	2000	300	20	
	3000	282	38	
	4000	264	56	
	5010	247	73	
	6000	228	92	
	7070	210	110	
	8140	180	140	
	9020			
$\frac{3}{4}$ " Radius Specimen No. 4 Thickness 1.88" Depth 3.94" Moment Arm 4"	570	210		 Sudden break. Good metal. Spongy spot much reduced. For total deflection add 0.006"
	1500	200	10	
	2500	189	21	
	3500	176	34	
	4500	160	50	
	6650	123	87	
	7560	104	106	
	8560	87	123	
	9740	61	149	
	10160			

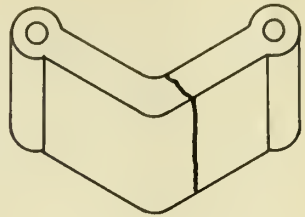
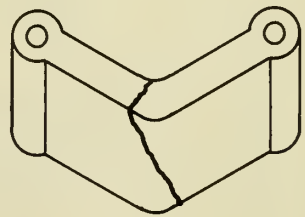
Year	1880	1881	1882
Jan	1.00	1.00	1.00
Feb	1.00	1.00	1.00
Mar	1.00	1.00	1.00
Apr	1.00	1.00	1.00
May	1.00	1.00	1.00
Jun	1.00	1.00	1.00
Jul	1.00	1.00	1.00
Aug	1.00	1.00	1.00
Sep	1.00	1.00	1.00
Oct	1.00	1.00	1.00
Nov	1.00	1.00	1.00
Dec	1.00	1.00	1.00

Year	1880	1881	1882
Jan	1.00	1.00	1.00
Feb	1.00	1.00	1.00
Mar	1.00	1.00	1.00
Apr	1.00	1.00	1.00
May	1.00	1.00	1.00
Jun	1.00	1.00	1.00
Jul	1.00	1.00	1.00
Aug	1.00	1.00	1.00
Sep	1.00	1.00	1.00
Oct	1.00	1.00	1.00
Nov	1.00	1.00	1.00
Dec	1.00	1.00	1.00

The following table shows the results of the experiments conducted during the year 1880, 1881, and 1882, in the investigation of the effects of the various factors mentioned in the preceding table. The results are given in the form of a table, the columns of which represent the different factors, and the rows represent the different years. The numbers in the table represent the results of the experiments, and are given in the form of a table, the columns of which represent the different factors, and the rows represent the different years. The numbers in the table represent the results of the experiments, and are given in the form of a table, the columns of which represent the different factors, and the rows represent the different years.

1" Radius Specimen No.1 Thickness 1.88" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	510	273		 Very quick break Spongy spot disappeared $\frac{1}{2} \times \frac{1}{4}$" blowhole For total deflec- tion add 0.006"
	1000	266	7	
	1500	259	14	
	2500	246	27	
	3500	231	42	
	4150	222	51	
	5800	193	80	
	6430	182	91	
	7320	164	109	
	8110	149	124	
	8900			
1" Radius Specimen No.2 Thickness 1.83" Depth 4.00" Moment Arm 4"	450	240		 Sudden break Very good metal Spongy spot scarcely evident. For total deflec- tion add 0.006"
	1000	233	7	
	1500	227	13	
	2500	213	27	
	3500	199	41	
	4140	191	49	
	4920	180	60	
	6130	162	78	
	7110	142	98	
	8020	125	115	
	9750	89	151	
	11340	49	191	
	11560			

No.	Description	Amount	
		1900	1901
1	Jan 1 Balance	100.00	100.00
2	Jan 10	100.00	100.00
3	Jan 20	100.00	100.00
4	Jan 30	100.00	100.00
5	Feb 10	100.00	100.00
6	Feb 20	100.00	100.00
7	Feb 30	100.00	100.00
8	Mar 10	100.00	100.00
9	Mar 20	100.00	100.00
10	Mar 30	100.00	100.00
11	Apr 10	100.00	100.00
12	Apr 20	100.00	100.00
13	Apr 30	100.00	100.00
14	May 10	100.00	100.00
15	May 20	100.00	100.00
16	May 30	100.00	100.00
17	Jun 10	100.00	100.00
18	Jun 20	100.00	100.00
19	Jun 30	100.00	100.00
20	Jul 10	100.00	100.00
21	Jul 20	100.00	100.00
22	Jul 30	100.00	100.00
23	Aug 10	100.00	100.00
24	Aug 20	100.00	100.00
25	Aug 30	100.00	100.00
26	Sep 10	100.00	100.00
27	Sep 20	100.00	100.00
28	Sep 30	100.00	100.00
29	Oct 10	100.00	100.00
30	Oct 20	100.00	100.00
31	Oct 30	100.00	100.00
32	Nov 10	100.00	100.00
33	Nov 20	100.00	100.00
34	Nov 30	100.00	100.00
35	Dec 10	100.00	100.00
36	Dec 20	100.00	100.00
37	Dec 30	100.00	100.00
38	Total	3650.00	3650.00

1" Radius Specimen No. 4 Thickness 1.84" Depth 4.00" Moment Arm 4"	Load	Extensometer Reading	Deflection $\frac{1}{1000}$ inches	Remarks
	520	201		 Very sudden break Spongy spot scarcely evident $\frac{3}{4} \times \frac{3}{8}$ blowhole. For total deflection add 0.007"
	1000	195	6	
	2000	181	20	
	3000	167	34	
	4000	150	51	
	5000	135	66	
	6000	117	84	
	7080	97	104	
	8040	73	128	
	8860			
1" Radius Specimen No. 3 Thickness 1.80" Depth 3.96" Moment Arm 4"	500	260		 Very sudden break Spongy spot very small. For total deflection add 0.008"
	1000	252	8	
	2000	237	23	
	3000	221	39	
	4000	204	56	
	5000	186	74	
	6000	167	93	
	7100	142	118	
	8120	120	140	
	9160	90	170	
	10390	50	210	
	10400			

UNIVERSITY OF
CHICAGO

LOAD, pounds,

6000

4000

2000

Sharp Corner No 1

Deflection, in inches

0.02 0.04 0.06 0.08 0.1 0.12

Sharp Corner No. 4

Deflection, in inches

0.02 0.04 0.06 0.08 0.10

6000

4000

2000

Sharp Corner, No 2

Deflection in inches

0.02 0.04 0.06 0.08 0.1 0.12

Sharp Corner No 5

Deflection, in, inches

0.02 0.04 0.06 0.08 0.10

DEFLECTION CURVES

Thesis of Klotz and Miles

Received of the Treasurer of the
County of [illegible] the sum of [illegible]
for [illegible]

Witness my hand and seal this [illegible] day of [illegible] 1871

[illegible signature]

By [illegible] Clerk of the Court

LOAD, pounds,

6000

4000

2000

 $\frac{1}{4}$ " Radius No. 1

Deflection in inches

0

.02

.04

.06

.08

.10

.12

 $\frac{1}{4}$ " Radius No. 2

Deflection, in inches

0

.02

.04

.06

.08

.10

6000

4000

2000

 $\frac{1}{4}$ " Radius, No. 3

Deflection in inches

0

.02

.04

.06

.08

.10

.12

 $\frac{1}{4}$ " Radius, No. 4

Deflection in inches

0

.02

.04

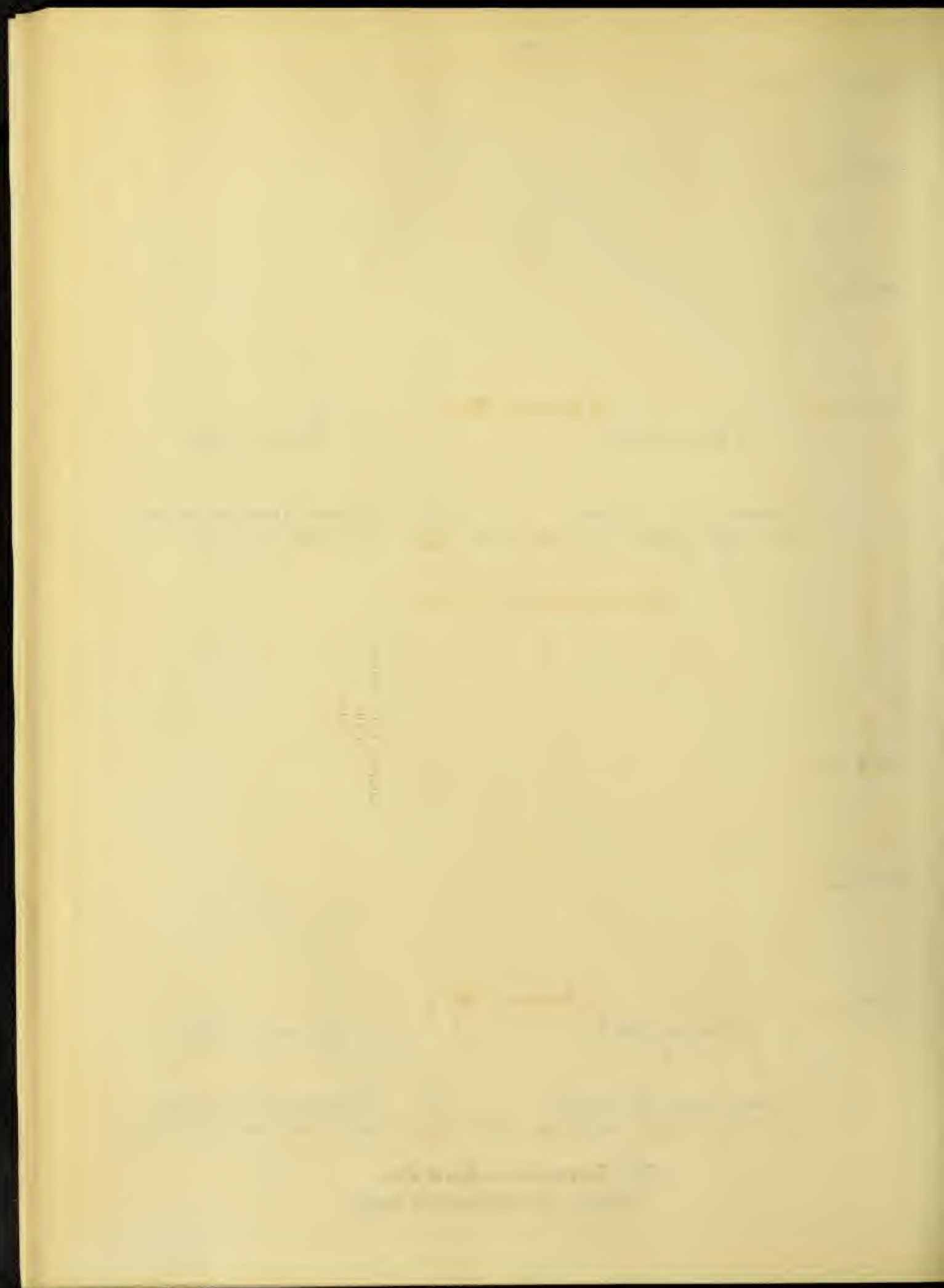
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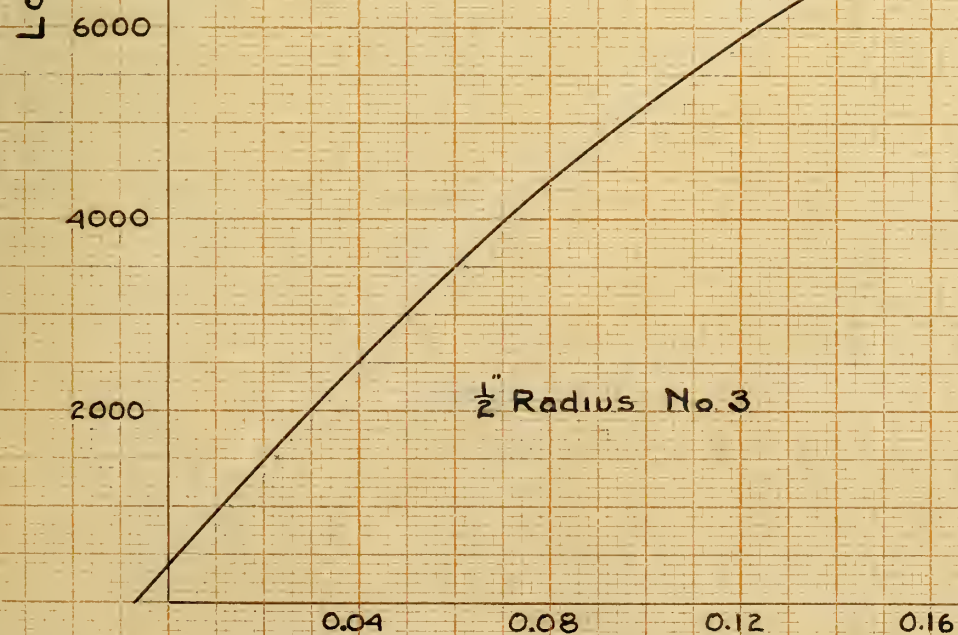
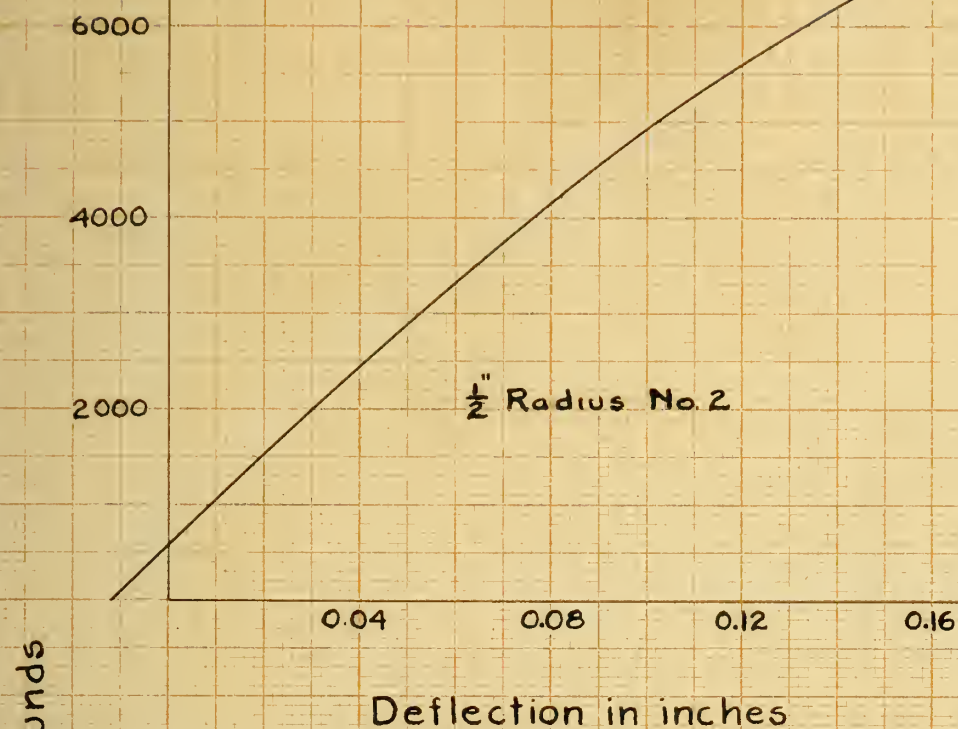
.08

.10

DEFLECTION CURVES

Thesis of Klotz and Miles





DEFLECTION CURVES
Thesis of Klotz and Miles

1870

1871

1872

1873

1874

1875

1876

1877

1878

1879

1880

1881

1882

6000

4000

2000

 $\frac{1}{2}$ Radius No. 4

0.04

0.08

0.12

0.16

Deflection in inches

Load in pounds

6000

4000

2000

 $\frac{1}{2}$ Radius No. 5

0.04

0.08

0.12

0.16

DEFLECTION CURVES
Thesis of Klotz and Miles

1891

1892

1893

1894 1895 1896 1897

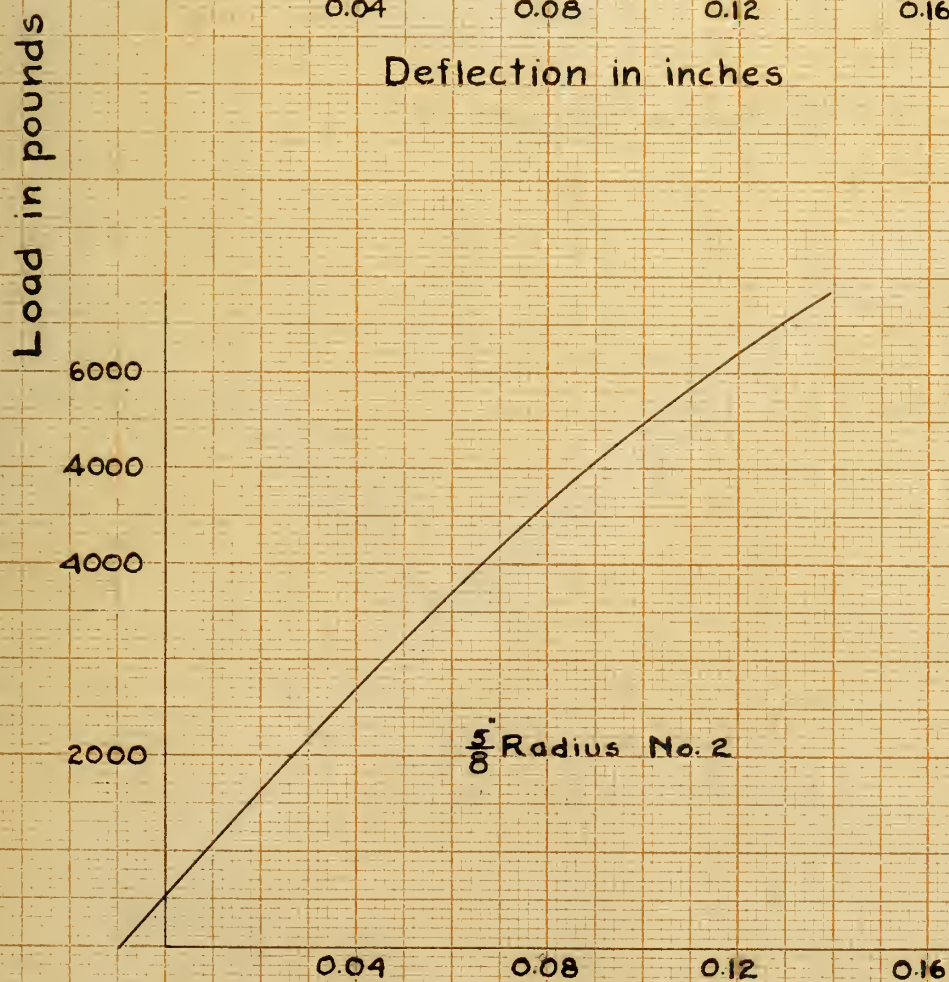
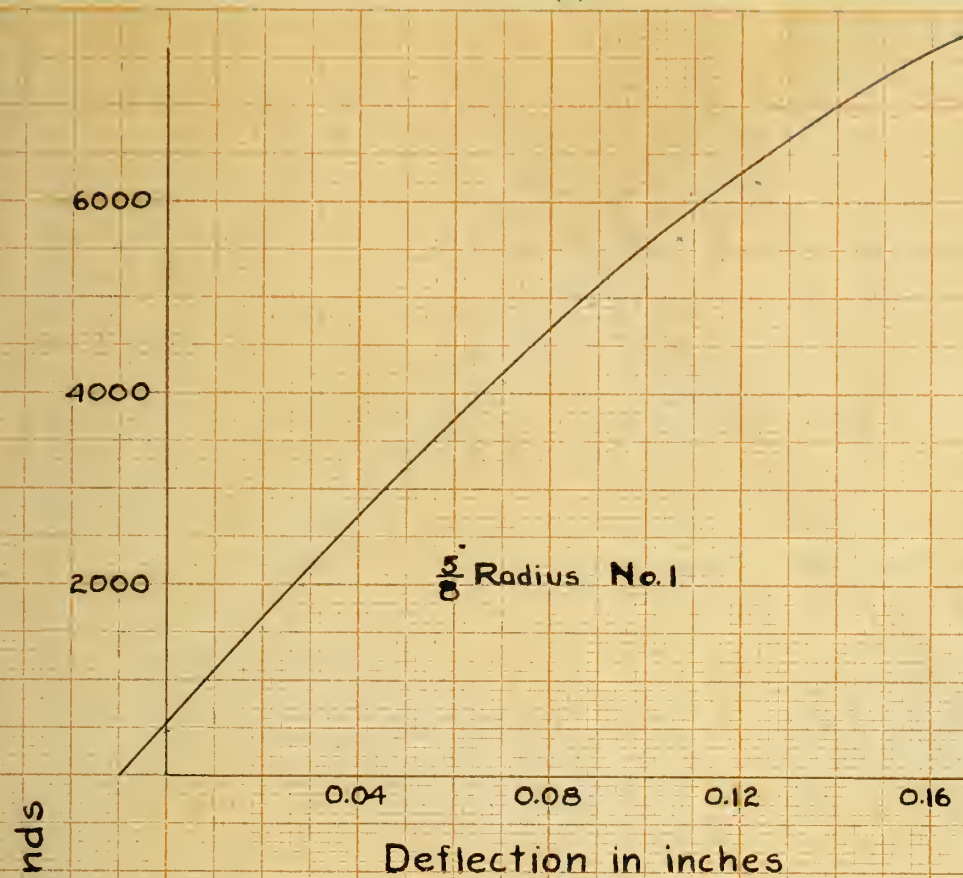
1898

1899

1900

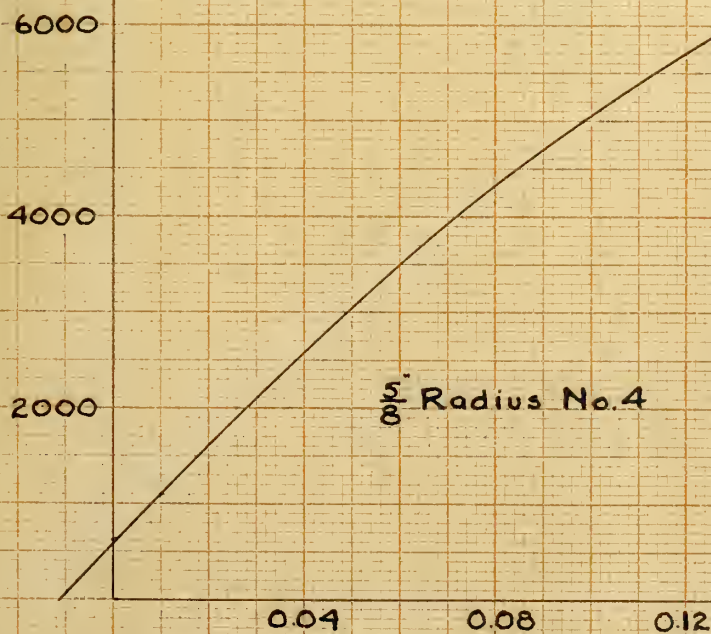
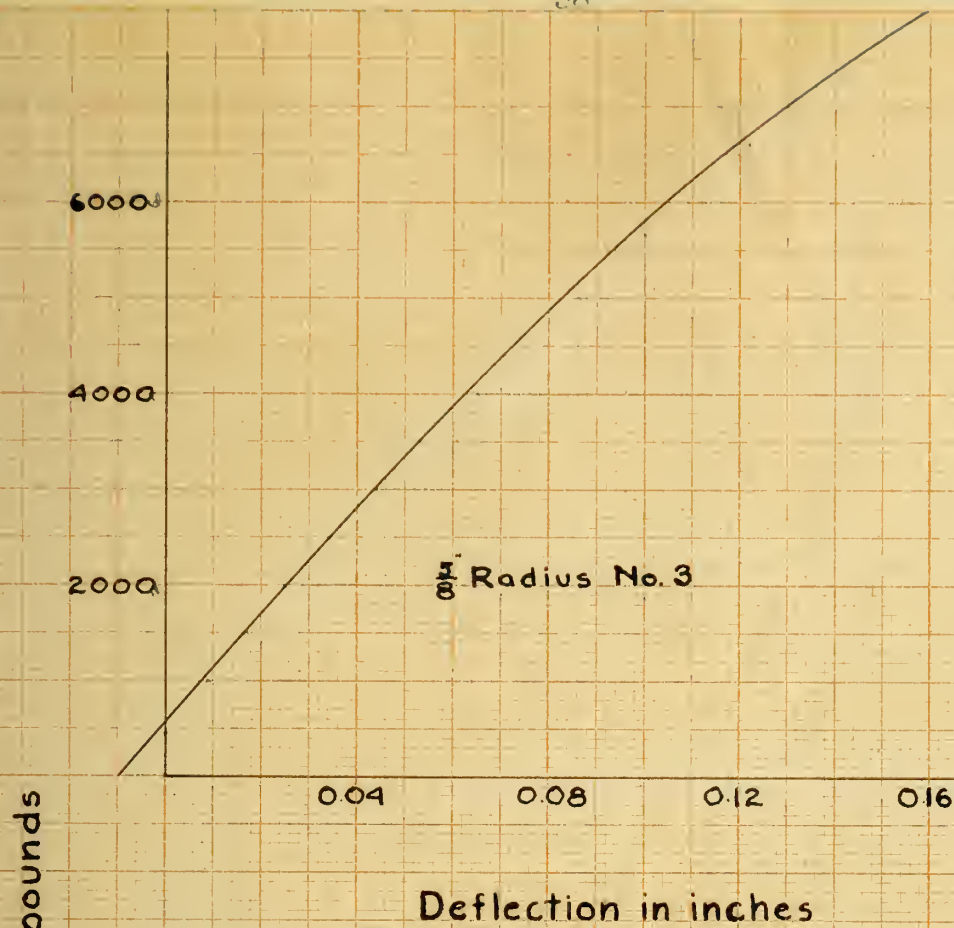
1901 1902 1903 1904

THE UNIVERSITY OF CHICAGO
PRESS



DEFLECTION CURVES
Thesis of Klotz and Miles





DEFLECTION CURVES
Thesis of Klotz and Miles

1874

1875

1876

1877

1878

1879

1880

1881

1882

1883

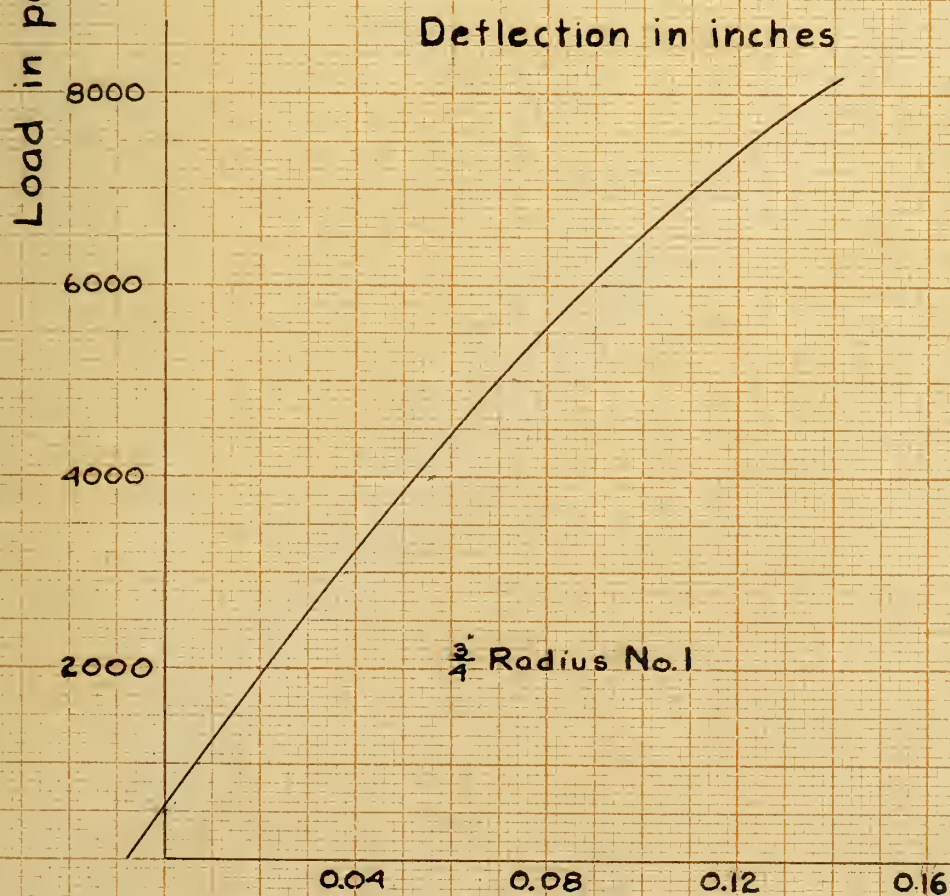
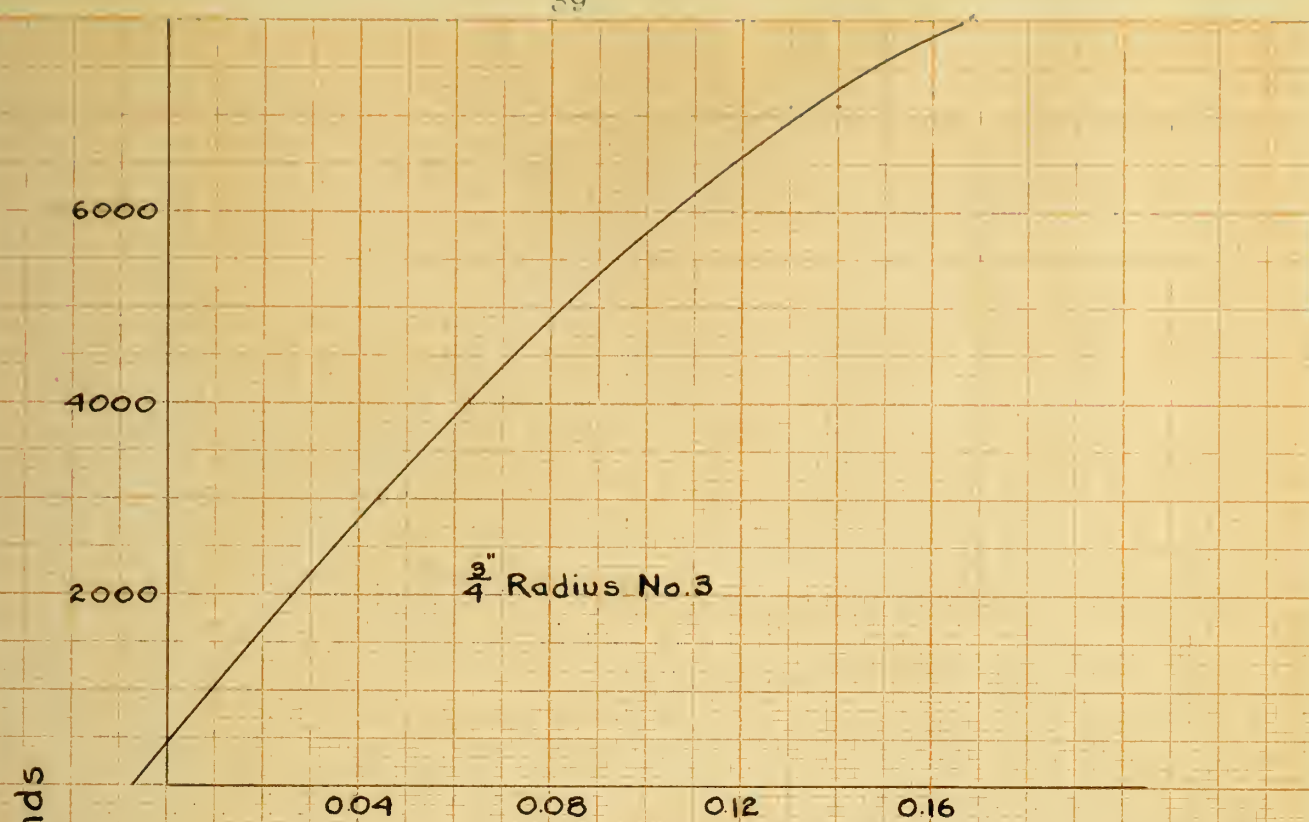
1874

1875

1876

1877

1878



DEFLECTION CURVES
Thesis of Klotz and Miles

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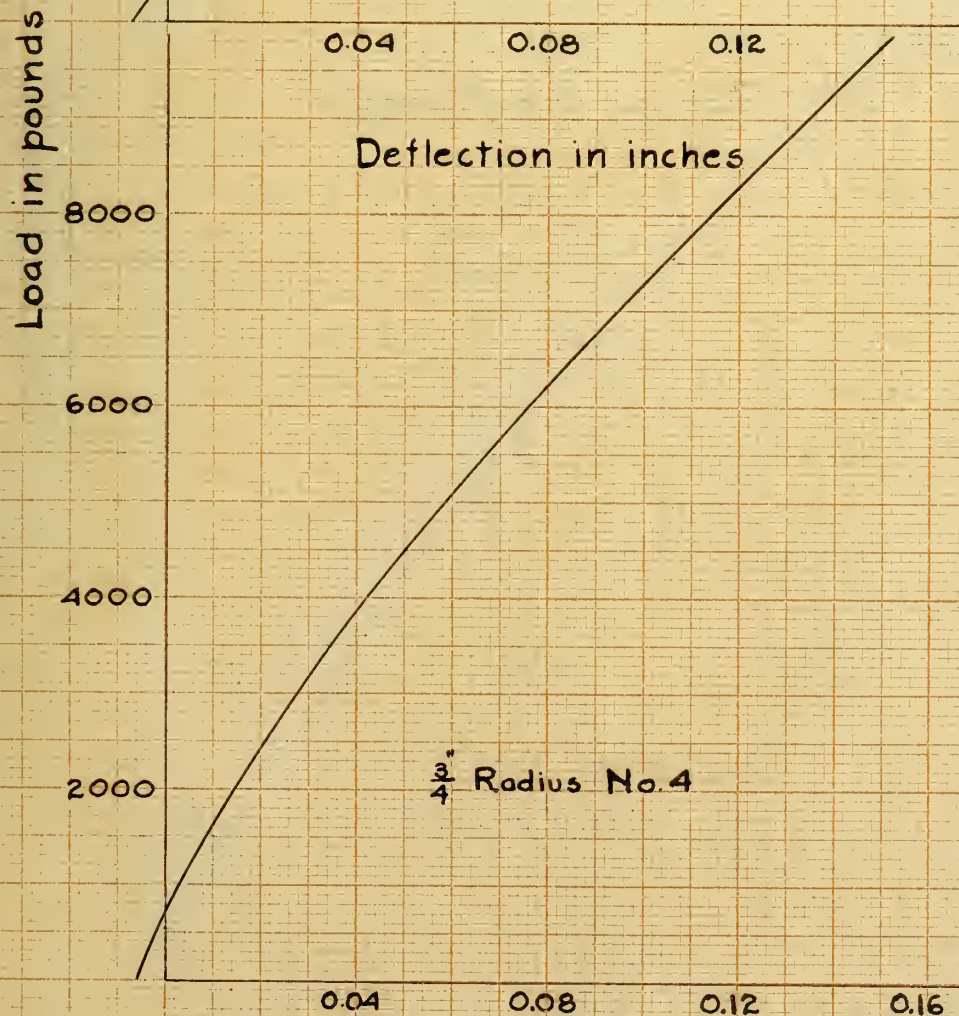
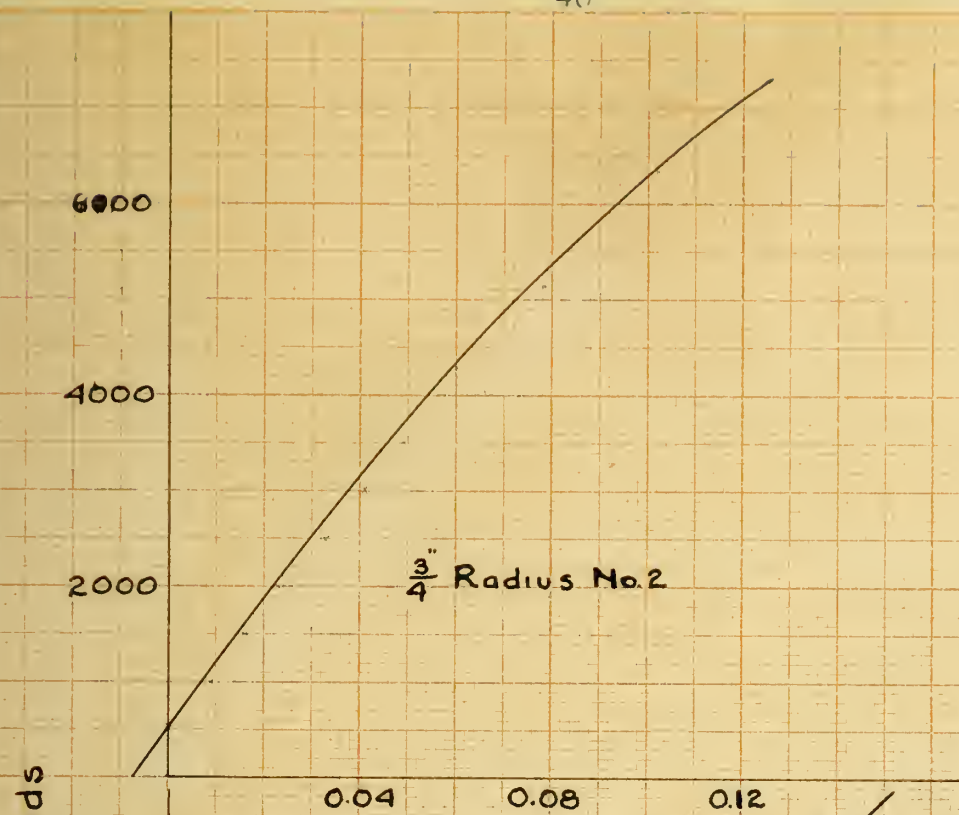
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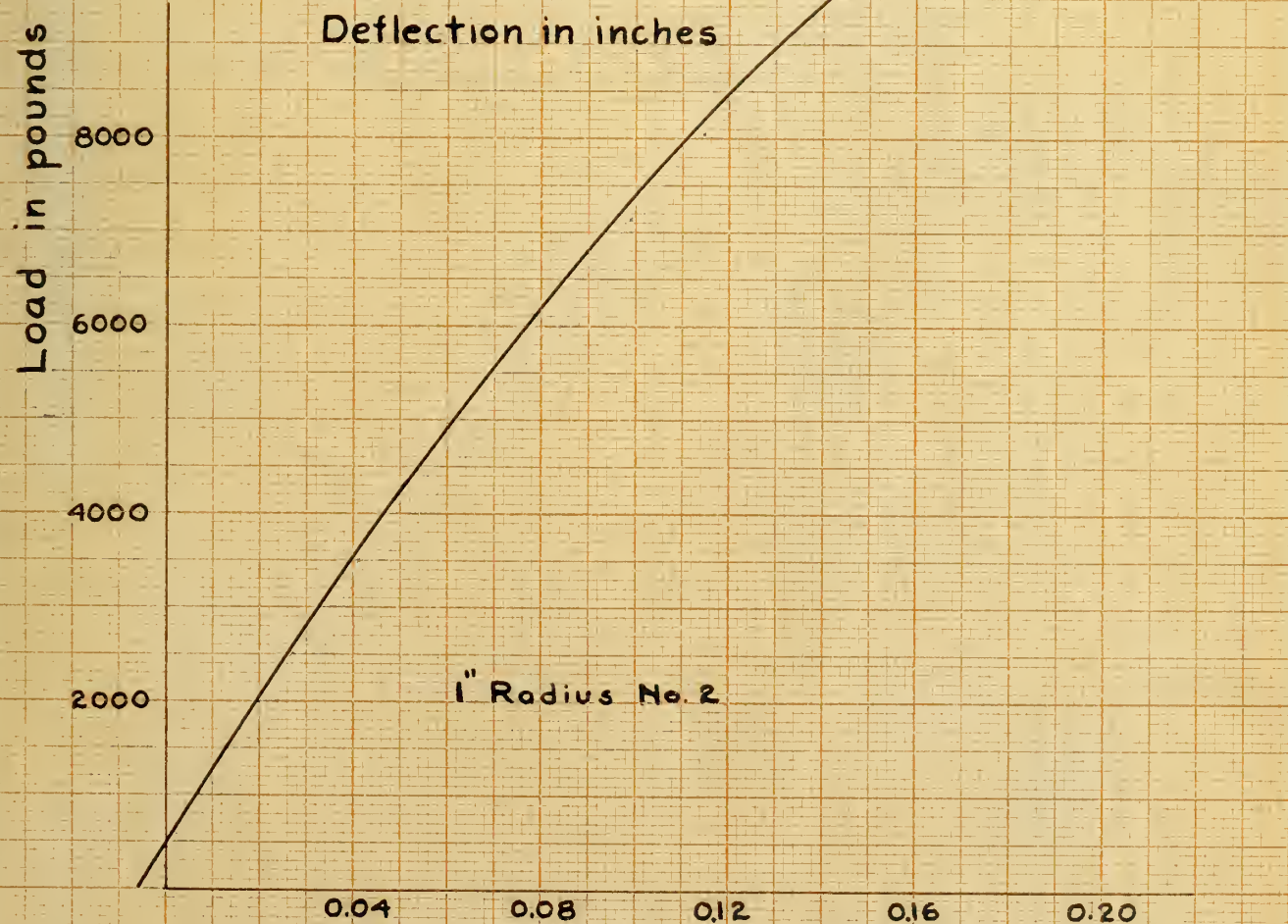
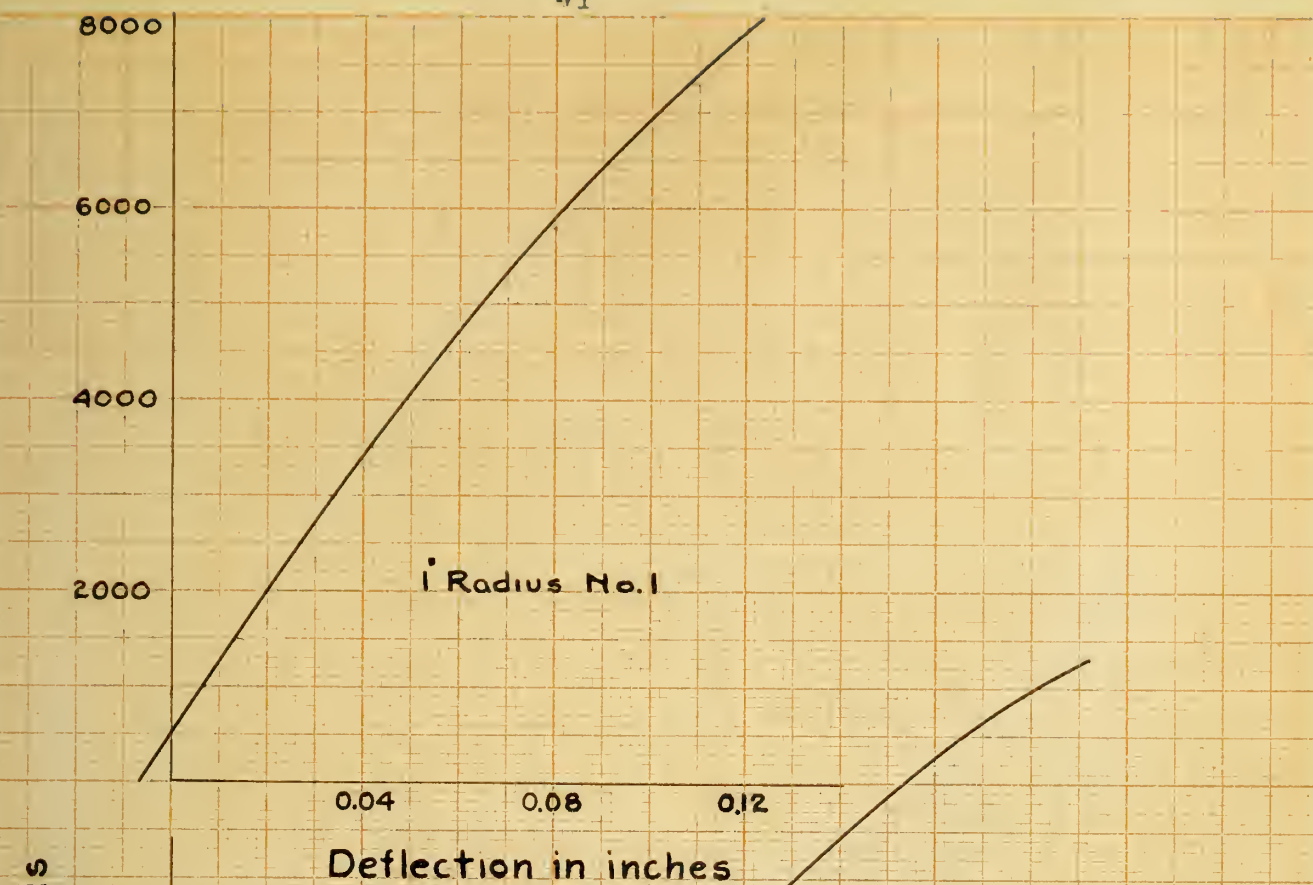
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THE UNIVERSITY OF CHICAGO



Deflection Curves
Thesis of Klotz and Miles





DEFLECTION CURVES
Thesis of Klotz and Miles

THE HISTORY OF

THE

REIGN OF

CHARLES THE FIRST

BY

JOHN BURNET

OF

THE UNIVERSITY OF OXFORD

IN TWO VOLUMES

VOLUME THE FIRST

THE SECOND PART

OF

THE REIGN

OF

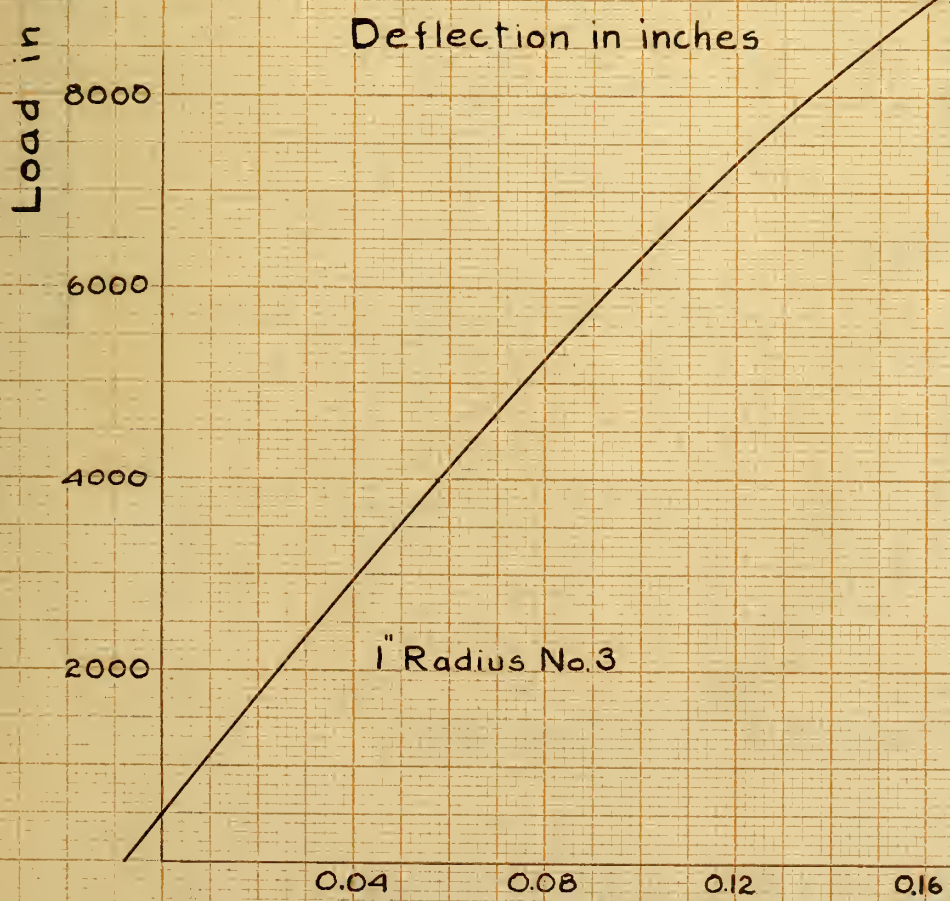
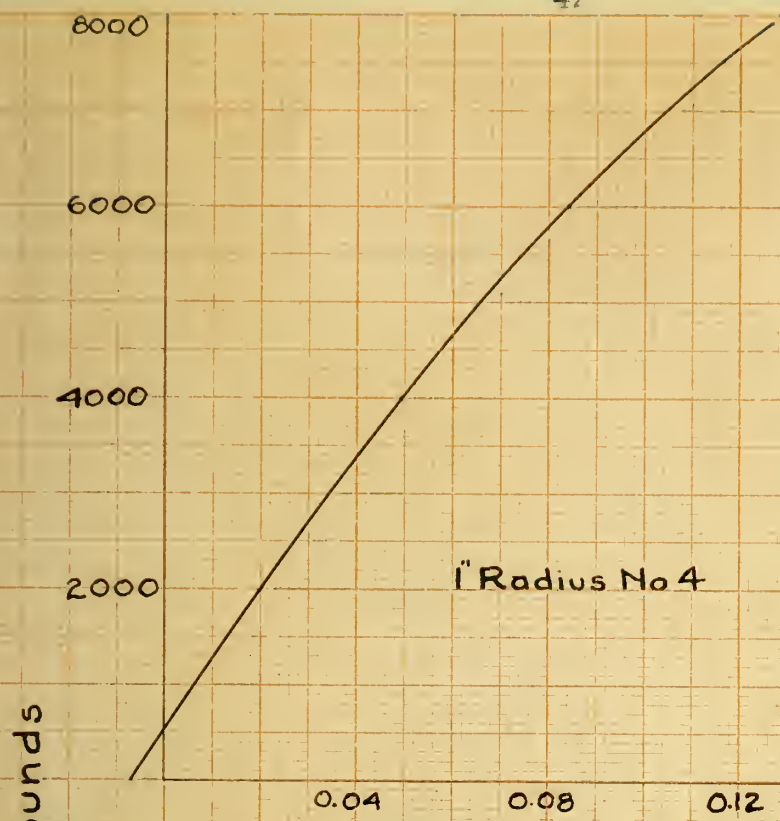
CHARLES THE FIRST

BY

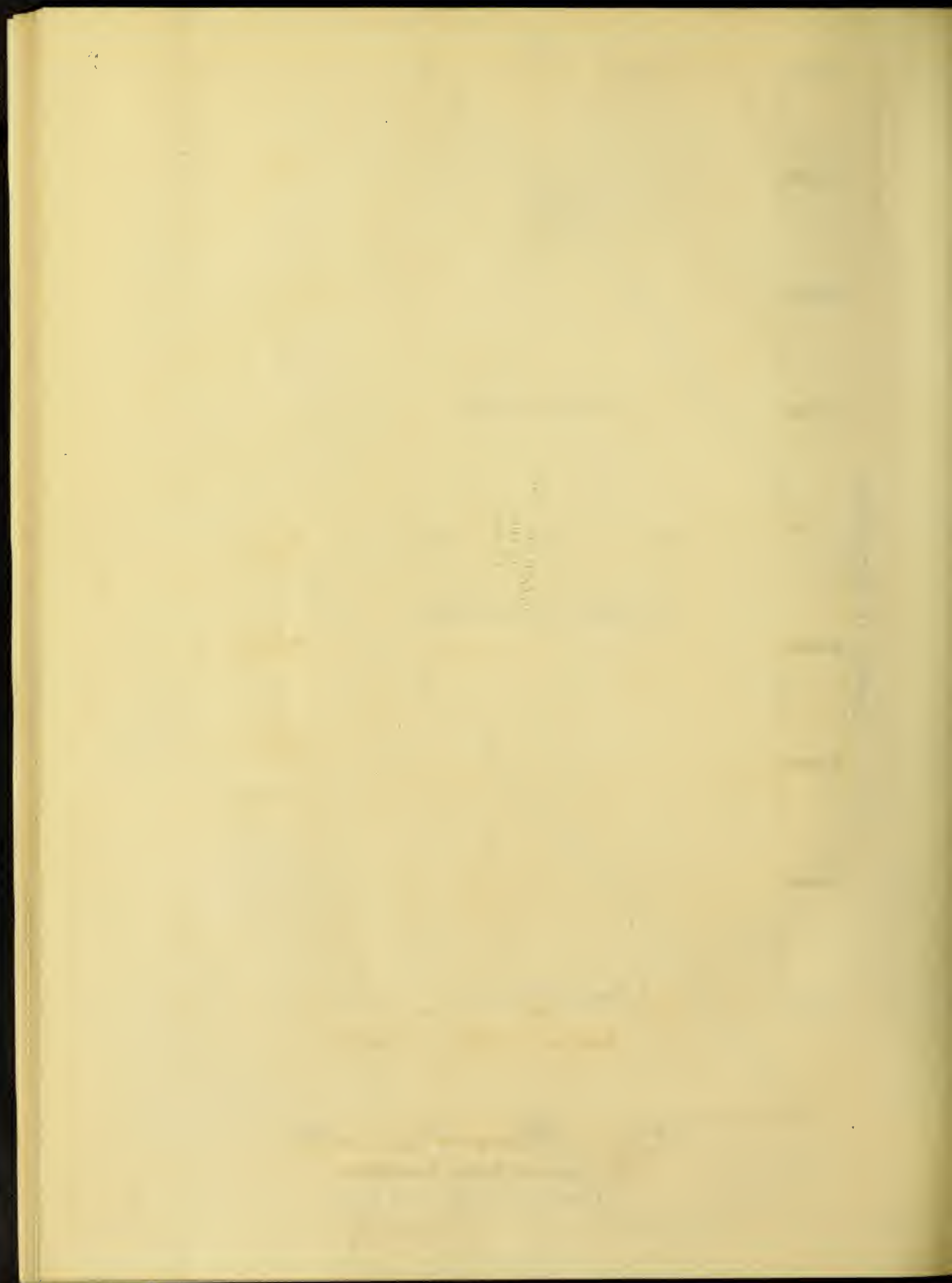
JOHN BURNET

OF

THE UNIVERSITY OF OXFORD



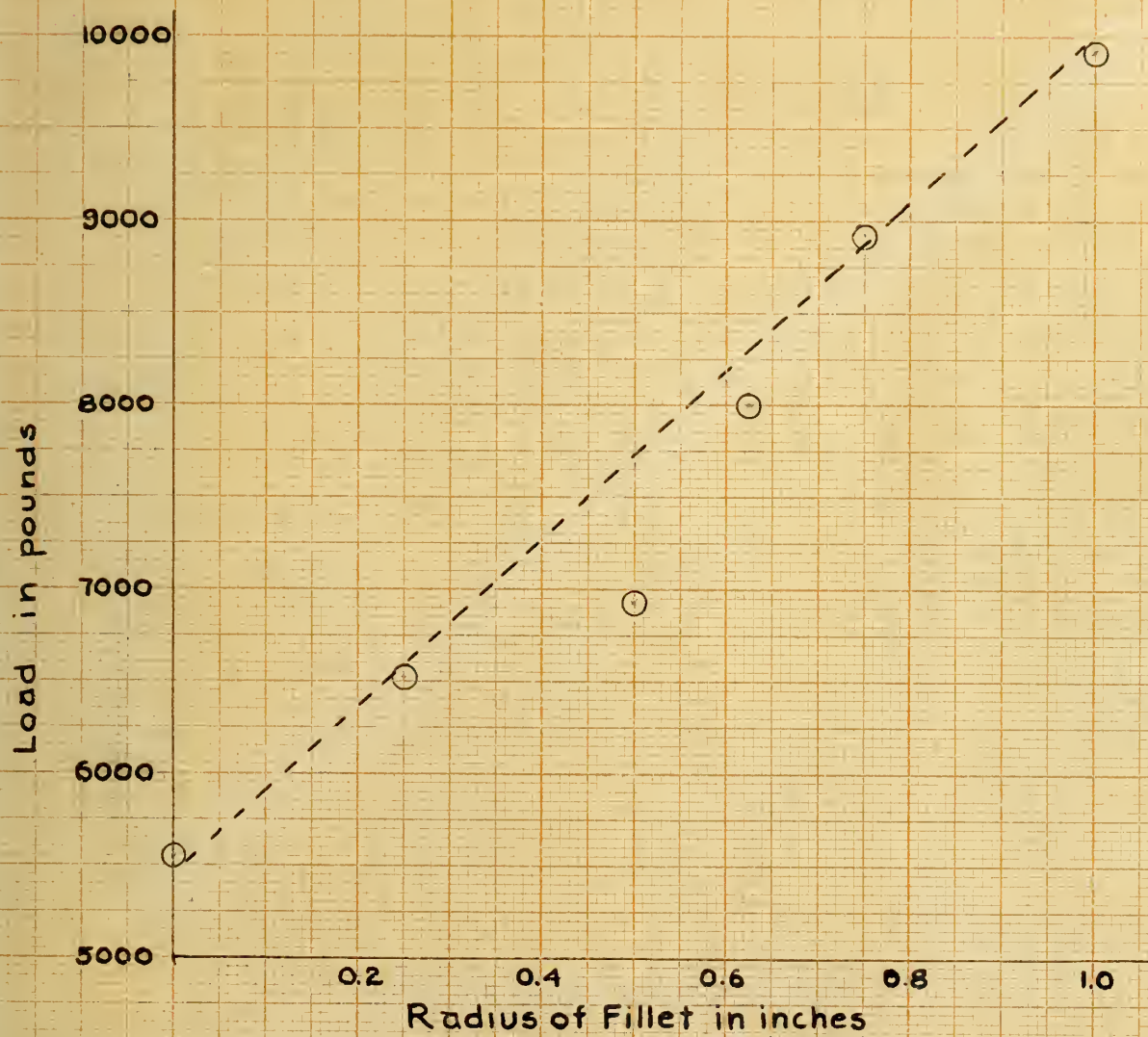
DEFLECTION CURVES
Thesis of Klotz and Miles





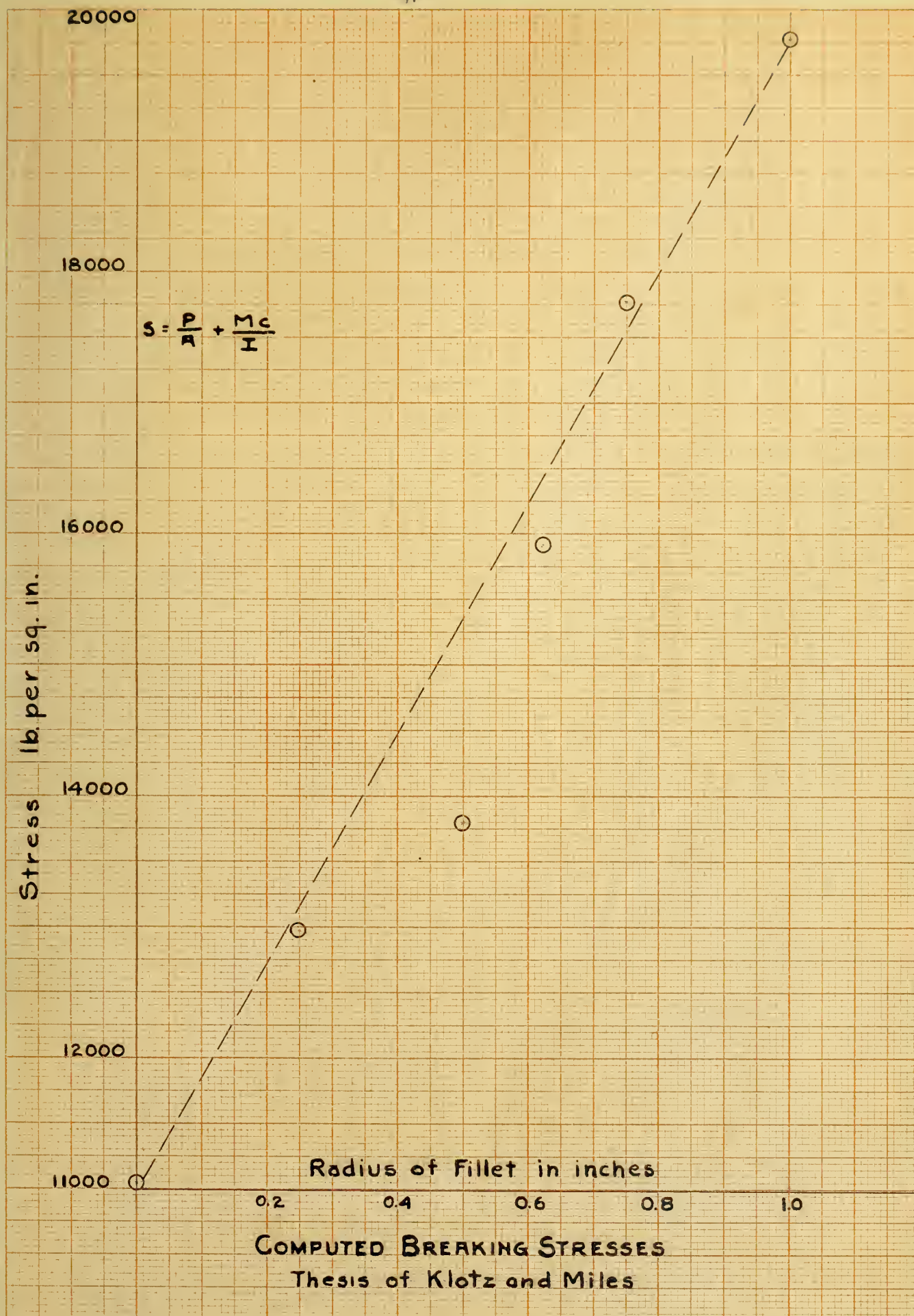
CURVES OF AVERAGE DEFLECTION
Thesis of Klotz and Miles





AVERAGE BREAKING LOADS
Thesis of Klotz and Miles

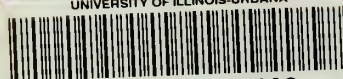








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